CALIFORNIA
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Appendix

Windows and Offices: A Study of Office Worker Performance and the Indoor Environment

TECHNICAL REPORT

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PREFACE

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

This document is one of 33 technical attachments to the final report of a larger research effort called *Integrated Energy Systems: Productivity and Building Science Program* (Program) as part of the PIER Program funded by the California Energy Commission (Commission) and managed by the New Buildings Institute.

As the name suggests, it is not individual building components, equipment, or materials that optimize energy efficiency. Instead, energy efficiency is improved through the integrated design, construction, and operation of building systems. The *Integrated Energy Systems: Productivity and Building Science Program* research addressed six areas:

- ***Productivity and Interior Environments***
- ***Integrated Design of Large Commercial HVAC Systems***
- ***Integrated Design of Small Commercial HVAC Systems***
- ***Integrated Design of Commercial Building Ceiling Systems***
- ***Integrated Design of Residential Ducting & Air Flow Systems***
- ***Outdoor Lighting Baseline Assessment***

The Program's final report (Commission publication #P500-03-082) and its attachments are intended to provide a complete record of the objectives, methods, findings and accomplishments of the *Integrated Energy Systems: Productivity and Building Science Program*. The final report and attachments are highly applicable to architects, designers, contractors, building owners and operators, manufacturers, researchers, and the energy efficiency community.

This document is the Appendices to Windows and Offices Report (Product # 2.6.10c) and contains the technical supporting analysis for the conclusions in the Windows and Offices Report.

The Buildings Program Area within the Public Interest Energy Research (PIER) Program produced these documents as part of a multi-project programmatic contract (#400-99-413). The Buildings Program includes new and existing buildings in both the residential and the non-residential sectors. The program seeks to decrease building energy use through research that will develop or improve energy efficient technologies, strategies, tools, and building performance evaluation methods.

For other reports produced within this contract or to obtain more information on the PIER Program, please visit www.energy.ca.gov/pier/buildings or contact the Commission's Publications Unit at 916-654-5200. All reports, guidelines and attachments are also publicly available at www.newbuildings.org/pier.

ABSTRACT

This document is the Appendices to Windows and Offices Report (Product #2.6.10) and contains the technical supporting analysis for the conclusions in the Windows and Offices Report.

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In this section results from the models developed for statistical analysis are presented for both the Call Center and Desktop study. For the different models, first a Descriptive Statistics table is presented that shows all the variables considered (*Variable*), the total number of records analyzed (*N*), mean (*Mean*), standard deviation (*StdDev*), min and max (*Minimum* and *Maximum*) for each of the variables. Following this, the reduced model table is presented. The reduced model consists of only those variables that showed up with more than 90% significance (<0.1 p-value) in the full model (not presented). For each variable, the beta coefficient (*Estimate*), standard error (*SE*), T-value (*Tvalue*) and P-value (*Pvalue*) are presented.

1.1 Call Center Study Models

In the Call Center study models, the outcome variable, average handling time, was measured in seconds. A negative estimate in the 'Reduced model' tables indicates a faster and hence better performance.

Variable	N	Mean	StdDev	Minimum	Maximum
Average Handeling Time	1171	6.87	1.20	1.85	9.32
Indoor Air Temperaure	1171	0.28	0.91	(2.33)	2.23
Total Calls Answered	1171	328.94	57.32	289.30	527.80
Floor Register Status	1171	1.91	1.27	-	4.00
Number of Task Lights	1171	0.94	0.31	-	2.00
Personal Fan	1171	0.26	0.44	-	1.00
Partition Height	1171	2.88	0.37	1.00	3.00
Primary View	1171	2.37	1.24	-	5.00
Break View	1171	2.65	1.89	-	5.00
First Hour of Shift	1171	0.05	0.21	-	1.00
Distance to North Wall	1171	1.83	4.07	-	15.00
Distance to South Wall	1171	2.45	4.25	-	13.00
Part Time Worker	1171	0.11	0.31	-	1.00
Team Leader	1171	0.05	0.22	-	1.00
Population	1171	89.05	3.91	81.00	98.00
group a	1171	0.07	0.25	-	1.00
group b	1171	0.10	0.30	-	1.00
group c	1171	0.10	0.30	-	1.00
group d	1171	0.07	0.26	-	1.00
group e	1171	0.11	0.31	-	1.00
group f	1171	0.12	0.32	-	1.00
group g	1171	0.11	0.31	-	1.00
group h	1171	0.11	0.31	-	1.00
group i	1171	0.12	0.32	-	1.00
Daylight (nL)	1171	1.29	1.20	-	3.59
Electric Light (nL)	1171	3.44	0.37	2.56	3.89
Total Light Range (nL)	1171	1.96	1.25	-	4.02
Average Seconds to Answer (nL)	1171	4.07	0.16	3.79	4.37
Years on Job (nL)	1171	6.62	1.21	5.00	9.11

Figure 1: September Daily model, descriptive statistics

Variable	Estimate	SE	Tvalue	Pvalue
Intercept	2.87	0.91	3.15	0.00
Total Light Range (nL)	0.12	0.03	3.95	<.0001
Average Seconds to Answer (nL)	0.63	0.19	3.25	0.00
Floor Register Status	(0.17)	0.03	(6.09)	<.0001
Number of Task Lights	0.50	0.12	4.29	<.0001
Partition Height	0.37	0.12	3.10	0.00
Primary View	(0.08)	0.04	(1.96)	0.05
Break View	(0.08)	0.03	(2.77)	0.01
Years on Job (nL)	0.06	0.03	1.83	0.07
Team Leader	(1.31)	0.19	(6.90)	<.0001
group a	0.54	0.15	3.55	0.00
group b	0.71	0.14	5.24	<.0001
group c	0.48	0.12	3.85	0.00
group d	0.31	0.13	2.35	0.02
group e	(0.22)	0.11	(1.96)	0.05
group g	(0.38)	0.11	(3.37)	0.00
group h	(0.28)	0.13	(2.17)	0.03
		Root	MSE	1.076
			R-Square	0.211

Figure 2: September Daily model

Variable	N	Mean	StdDev	Minimum	Maximum
Average Handeling Time	832	7.00	1.25	2.08	9.32
Daylight (nL)	832	1.49	0.97	-	3.21
Daylight Range (nL)	832	0.88	0.78	-	2.80
First Hour of Shift	832	0.07	0.25	-	1.00
Indoor Air Temperaure	832	74.33	0.88	71.60	76.88
Outside Air Delivered	832	1.15	0.35	0.14	2.01
Total Calls Answered	832	32.44	7.57	9.00	57.70
Average Seconds to Answer (nL)	832	4.08	0.47	3.50	5.98
Floor Register Status	832	1.22	1.63	-	4.00
Number of Task Lights	832	0.95	0.31	-	2.00
Personal Fan	832	0.21	0.41	-	1.00
Partition Height	832	2.85	0.39	1.00	3.00
Primary View	832	2.42	1.26	-	5.00
Break View	832	2.75	1.76	-	5.00
Electric Light (nL)	832	2.86	0.80	0.78	3.94
Total Light Range (nL)	832	2.36	1.28	-	3.76
Years on Job (nL)	832	6.62	1.17	5.08	9.12
Distance to North Wall	832	1.69	3.85	-	15.00
Distance to South Wall	832	2.86	4.59	-	13.00
Part Time Worker	832	0.11	0.31	-	1.00
Team Leader	832	0.05	0.21	-	1.00
Population	832	58.09	5.48	24.00	73.50
group a	832	0.08	0.27	-	1.00
group b	832	0.09	0.28	-	1.00
group c	832	0.08	0.27	-	1.00
group d	832	0.06	0.24	-	1.00
group e	832	0.11	0.32	-	1.00
group f	832	0.11	0.31	-	1.00
group g	832	0.11	0.32	-	1.00
group h	832	0.11	0.32	-	1.00
group i	832	0.13	0.33	-	1.00

Figure 3: November Daily model, descriptive statistics

Variable	Estimate	SE	Tvalue	Pvalue
Intercept	2.89	1.14	2.54	0.01
Daylight (nL)	0.13	0.04	2.94	0.00
Total Calls Answered	(0.08)	0.02	(4.11)	<.0001
Average Seconds to Answer (nL)	0.44	0.24	1.82	0.07
Floor Register Status	(0.05)	0.02	(2.10)	0.04
Partition Height	0.38	0.13	3.00	0.00
Break View	(0.10)	0.02	(3.98)	<.0001
Years on Job (nL)	0.12	0.05	2.26	0.02
Distance to North Wall	(0.02)	0.01	(1.81)	0.07
Team Leader	(1.15)	0.22	(5.17)	<.0001
Population	0.06	0.01	4.78	<.0001
group e	(0.74)	0.17	(4.40)	<.0001
group f	(0.64)	0.16	(4.01)	<.0001
group g	(0.60)	0.16	(3.69)	0.00
group h	(0.69)	0.17	(4.05)	<.0001
group i	(0.40)	0.21	(1.89)	0.06
		Root	MSE	1.110
			R-Square	0.223

Figure 4: November Daily model

Variable	N	Mean	StdDev	Minimum	Maximum
Average Handeling Time (nL)	6200	1.93	0.39	0.29	3.17
Daylight (nL)	6200	1.45	1.07	-	3.76
Floor Register Status	6200	1.19	1.62	-	4.00
Number of Task Lights	6200	0.94	0.32	-	2.00
Personal Fan	6200	0.19	0.40	-	1.00
Partition Height	6200	2.88	0.34	1.00	3.00
Primary View	6200	2.42	1.25	-	5.00
Break View	6200	2.79	1.75	-	5.00
Electric Light (nL)	6200	2.85	0.79	0.78	3.94
Total Light Range (nL)	6200	2.40	1.26	-	3.76
Years on Job (nL)	6200	6.65	1.19	5.08	9.12
Total Calls Answered	6200	33.38	9.88	6.40	61.20
Average Seconds to Answer (nL)	6200	4.02	0.54	3.48	5.76
Indoor Air Temperaure	6200	74.53	1.08	71.08	77.14
Population	6200	59.81	11.95	18.00	75.00
Outside Air Delivered	6200	1.19	0.45	0.12	2.06
Distance to South Wall	6200	2.97	4.62	-	13.00
Distance to North Wall	6200	1.66	3.86	-	15.00
Part Time Worker	6200	0.10	0.31	-	1.00
Team Leader	6200	0.02	0.13	-	1.00
First Hour of Shift	6200	0.06	0.23	-	1.00
Last Hour of Shift	6200	6.93	7.18	-	42.91
group a	6200	0.08	0.27	-	1.00
group b	6200	0.10	0.30	-	1.00
group c	6200	0.08	0.27	-	1.00
group d	6200	0.06	0.24	-	1.00
group e	6200	0.11	0.31	-	1.00
group f	6200	0.11	0.31	-	1.00
group g	6200	0.11	0.32	-	1.00
group h	6200	0.11	0.31	-	1.00
group i	6200	0.12	0.33	-	1.00

Figure 5: November Hourly model, descriptive statistics

Variable	Estimate	Error	Tvalue	Pvalue
Intercept	0.76	0.42	1.80	0.07
Floor Register Status	(0.01)	0.00	(3.05)	0.00
Partition Height	0.09	0.02	4.75	<.0001
Break View	(0.01)	0.00	(4.43)	<.0001
Electric Light (nL)	(0.03)	0.01	(3.43)	0.00
Years on Job (nL)	0.01	0.01	1.66	0.10
Total Calls Answered	(0.01)	0.00	(9.18)	<.0001
Average Seconds to Answer (nL)	0.07	0.01	5.47	<.0001
Indoor Air Temperaure	0.01	0.01	1.69	0.09
Population	0.01	0.00	10.03	<.0001
Outside Air Delivered	(0.04)	0.01	(2.93)	0.00
Distance to North Wall	(0.00)	0.00	(2.68)	0.01
Team Leader	(0.18)	0.04	(4.45)	<.0001
group c	(0.06)	0.02	(2.51)	0.01
group e	(0.17)	0.02	(7.87)	<.0001
group f	(0.15)	0.02	(7.41)	<.0001
group g	(0.15)	0.02	(6.96)	<.0001
group h	(0.14)	0.02	(6.10)	<.0001
group i	(0.11)	0.03	(4.02)	<.0001
		Root	MSE	0.376
			R-Square	0.078

Figure 6: November Hourly model

1.2 Desktop Study Models

Variable	N	MEAN	STD	MIN	MAX
Memory Test Score	316.00	10.56	4.08	1.00	21.00
Backwards Numbers Score	551.00	5.23	1.45	-	7.00
Number Search Score	563.00	15.64	4.80	8.08	39.89
Letter Search Score	566.00	5.06	2.38	1.38	15.20
Landolt C Score	562.00	3.58	2.03	1.14	14.28
Daylight (nL)	551.00	2.28	1.52	-	6.00
Electric Light	551.00	3.40	0.42	1.74	4.63
Air Temperature	551.00	74.49	1.41	70.39	78.40
Total Illuminance	551.00	57.28	37.53	13.44	421.39
Electric Light	551.00	32.72	13.88	5.70	102.45
Years with Company	551.00	14.65	7.99	-	35.00
Education	551.00	1.39	1.03	-	4.00
Age	551.00	2.30	0.85	-	4.00
Gender	551.00	0.41	0.49	-	1.00
Dept A	551.00	0.09	0.29	-	1.00
Dept B	551.00	0.06	0.23	-	1.00
Dept C	551.00	0.11	0.31	-	1.00
Dept D	551.00	0.09	0.29	-	1.00
Dept E	551.00	0.07	0.25	-	1.00
Dept F	551.00	0.08	0.27	-	1.00
Dept G	551.00	0.10	0.30	-	1.00
Dept K	551.00	0.04	0.19	-	1.00
Dept H	551.00	0.16	0.36	-	1.00
Dept I	551.00	0.05	0.23	-	1.00
Dept J	551.00	0.06	0.24	-	1.00
High Monitor Resolution	551.00	0.26	0.44	-	1.00
Higher Monitor Resolution	551.00	0.37	0.48	-	1.00
CSC Building	551.00	0.71	0.45	-	1.00
Distance To External Wall	551.00	17.32	9.11	6.00	60.00
Skylight Zone	551.00	0.68	1.17	-	3.00
Break View	551.00	1.75	1.67	-	5.00
Primary View	551.00	1.44	1.85	-	5.00
Floor Register Status	551.00	1.70	1.54	-	4.00
Glare from Windows	551.00	0.58	0.91	-	3.00
Session 2	551.00	0.31	0.46	-	1.00
Session 3	551.00	0.25	0.44	-	1.00
Session 4	551.00	0.08	0.27	-	1.00
Correct on 1st Memory Test	316.00	14.51	3.92	5.00	23.00
Imagined per Memory Test	316.00	4.22	3.21	-	17.00

Figure 7: Mini-Tests model, descriptive statistics

The descriptive statistics given in Figure 7 apply to all Desktop Study Models of the Mini-Tests performance.

Variable	Estimate	Error	Tvalue	Pvalue
Intercept	(30.92)	10.69	(2.89)	0.00
Imagined per Memory Test	0.40	0.05	7.57	<.0001
Correct on 1st Memory Test	0.56	0.04	12.89	<.0001
Air Temperature	0.42	0.14	2.94	0.00
Age	0.53	0.21	2.52	0.01
Gender	(1.38)	0.35	(3.99)	<.0001
Dept K	(2.27)	1.14	(1.99)	0.05
Dept H	(1.07)	0.50	(2.15)	0.03
High Monitor Resolution	(1.34)	0.40	(3.32)	0.00
Break View	0.19	0.10	1.89	0.06
Primary View	0.34	0.13	2.64	0.01
Glare from Windows	(0.58)	0.27	(2.16)	0.03
Session 3	(0.62)	0.34	(1.85)	0.07
		Root	MSE	2.906
			R-Square	0.511

Figure 8: Mini-Tests model, Memory Test

In the Memory Test model, the score was determined by the number of correctly remembered objects. Mean of the score on this test was 10.56. A positive estimate in the above table indicates better performance.

Variable	Estimate	Error	Tvalue	Pvalue
Intercept	4.99	0.19	26.51	<.0001
Daylight (nL)	0.23	0.05	4.97	<.0001
Years with Company	(0.02)	0.01	(2.63)	0.01
Education	0.15	0.06	2.38	0.02
Gender	(0.34)	0.13	(2.64)	0.01
Dept D	(0.53)	0.21	(2.53)	0.01
Dept E	(0.82)	0.25	(3.26)	0.00
Dept J	0.77	0.25	3.03	0.00
Primary View	0.10	0.05	2.17	0.03
Glare from Windows	(0.26)	0.09	(2.85)	0.00
		Root	MSE	1.373
			R-Square	0.126

Figure 9: Mini-Tests model, Backwards Numbers

In the Backwards Numbers model, the score was determined by the count of how many digits the participant could correctly remember before making two mistakes. Mean of the score on this test was 5.23. A positive estimate in the above table indicates better performance.

Variable	Estimate	Error	Tvalue	Pvalue
Intercept	14.36	0.69	20.80	<.0001
Years with Company	0.06	0.03	1.96	0.05
Age	0.67	0.27	2.46	0.01
Gender	0.93	0.42	2.23	0.03
Dept A	(2.05)	0.77	(2.67)	0.01
Dept B	(2.56)	0.95	(2.70)	0.01
Dept G	(1.77)	0.76	(2.32)	0.02
Dept H	(1.48)	0.62	(2.38)	0.02
Higher Monitor Resolution	1.53	0.48	3.21	0.00
Break View	(0.26)	0.12	(2.12)	0.03
Primary View	(0.26)	0.15	(1.71)	0.09
Floor Register Status	(0.66)	0.15	(4.57)	<.0001
Glare from Windows	1.09	0.31	3.54	0.00
		Root	MSE	4.573
			R-Square	0.111

Figure 10: Mini-Tests model, Number Search

In the Number Search model, the outcome variable was measured in seconds. Mean of performance on this test was 15.64 seconds. A negative estimate in the above table indicates a faster and hence better performance.

Variable	Estimate	Error	Tvalue	Pvalue
Intercept	4.71	0.34	13.81	<.0001
Years with Company	0.03	0.01	2.29	0.02
Age	0.31	0.13	2.38	0.02
Gender	(0.60)	0.20	(3.04)	0.00
Dept J	0.90	0.42	2.14	0.03
High Monitor Resolution	(0.58)	0.26	(2.20)	0.03
Higher Monitor Resolution	(0.80)	0.25	(3.15)	0.00
Skylight Zone	0.26	0.09	2.70	0.01
Floor Register Status	0.20	0.07	2.87	0.00
Session 2	(0.89)	0.23	(3.84)	0.00
Session 3	(1.34)	0.25	(5.45)	<.0001
Session 4	(1.09)	0.38	(2.91)	0.00
		Root	MSE	2.240
			R-Square	0.132

Figure 11: Mini-Tests model, Letter Search

In the Letter Search model, the outcome variable was measured in seconds. Mean of performance on this test was 5.06 seconds. A negative estimate in the above table indicates a faster and hence better performance.

Variable	Estimate	Error	Tvalue	Pvalue
Intercept	(7.94)	5.23	(1.52)	0.13
Air Temperature	0.15	0.07	2.12	0.03
Education	0.26	0.08	3.33	0.00
Age	0.47	0.09	5.02	<.0001
Dept F	(0.67)	0.32	(2.10)	0.04
High Monitor Resolution	(1.17)	0.21	(5.49)	<.0001
Higher Monitor Resolution	(1.05)	0.19	(5.41)	<.0001
CSC Building	(1.03)	0.28	(3.62)	0.00
Primary View	0.11	0.05	2.43	0.02
Floor Register Status	0.18	0.07	2.42	0.02
Session 3	(0.56)	0.18	(3.07)	0.00
Session 4	(0.77)	0.30	(2.59)	0.01
		Root	MSE	1.838
			R-Square	0.195

Figure 12: Mini-Tests model, Landolt C

In the Landolt C model, the outcome variable was measured in seconds. Mean of performance on this test was 3.58 seconds. A negative estimate in the above table indicates a faster and hence better performance.

2. PEARSON'S CORRELATIONS RESULTS

Category	Variables	Range	Measured Physical Vaiables					
			Daylight (nL)	Primary View	Skylight Zone	Distance to Exterior Wall	Floor Register Status	Air Temperature
View								
	My view is interesting	(1-7) Disagree-Agree	0.29	0.55				
	My view is relaxing	(1-7) Disagree-Agree	0.17	0.43				
	My view is distracting	(1-7) Disagree-Agree				0.21		
	My view is boring	(1-7) Disagree-Agree				0.35		
	I have a large size window view	(1-7) Very Small-Very Large	0.32	0.77				
	I have a view of the sky	(1-4) None-A lot	0.35	0.77				
	I have a view of trees	(1-4) None-A lot	0.27	0.78				
	I have a view of other plants	(1-4) None-A lot	0.28	0.78				
	I have a view of other buildings	(1-4) None-A lot	0.41	0.70				
	I have a view of cars outside	(1-4) None-A lot	0.34	0.70				
	I have a view of people outside	(1-4) None-A lot	0.29	0.74				
Lighting								
	I have no lighting problems	(0-1) No-Yes						
	Lighting is just right	(1-7) Never-Always	0.13					
	Lighting is too bright	(1-7) Never-Always			0.17			
	Lighting is too dim	(1-7) Never-Always				0.14		
	Lighting is too dull	(1-7) Never-Always						
	There is not enough daylight	(0-1) No-Yes				0.23		
	There is too much daylight	(0-1) No-Yes	0.19	0.16				
	There is not enough control of daylight	(0-1) No-Yes						0.13
	There is not enough electric light	(0-1) No-Yes						
	There is not too much electric light	(0-1) No-Yes			0.20			
	There is not enough control of electric light	(0-1) No-Yes						
	There is not enough sunlight	(0-1) No-Yes				0.13		
	There is too much sunlight	(0-1) No-Yes	0.30	0.14				0.19
	I am uncomfortable due to no task lights	(0-1) No-Yes				0.22	0.16	
	Reflections of electric lights bother me	(1-7) Never-Always				0.22		
	Reflections of windows bother me	(1-7) Never-Always	0.26	0.30				0.19
	Reflections of skylights bother me	(1-7) Never-Always	0.13		0.34			
Thermal Comfort								
	I have no temperature problems	(0-1) No-Yes						
	Temperature is too cold	(1-7) Never-Always						
	Temperature is too hot	(1-7) Never-Always					0.20	
	My workspace is colder than other areas	(0-1) No-Yes		0.17				
	My workspace is hotter than other areas	(0-1) No-Yes						
	Air movement is too low	(0-1) No-Yes					0.25	
	The window is drafty	(0-1) No-Yes						
	Incoming sun is uncomfortable	(0-1) No-Yes						
	Heat from equipment is uncomfortable	(0-1) No-Yes						
Air Quality								
	Air is too stuffy	(1-7) Never-Always				0.14		
	Air is too humid	(1-7) Never-Always						
	Air is too dry	(1-7) Never-Always					0.29	
Acoustics								
	Noise level is noticable	(1-7) Never-Always	0.13					0.13
	Noise level is distracting	(1-7) Never-Always						0.14
	I wear headphones while working	(1-7) Never-Always			0.25			
	I keep a radio on while working	(1-7) Never-Always						
	I am distracted due to people talking	(0-1) No-Yes						
	I am distracted due to telephones ringing	(0-1) No-Yes						
	Office equipment noise is noisy	(0-1) No-Yes				0.15		
	Mechanical ventilation system is noisy	(0-1) No-Yes						
	I am distracted by noise from office lights	(0-1) No-Yes				0.14		
	I am distracted by noise from traffic	(0-1) No-Yes		0.21				
	I am distracted by noise from consruction	(0-1) No-Yes						

Figure 13: <u>Positive</u> Pearson's correlations, questionnaire responses and physical measurements

Category	Variables	Range	Measured Physical Vaiables					
			Daylight (nL)	Primary View	Skylight Zone	Distance to Exterior Wall	Floor Register Status	Air Temperature
View								
	My view is interesting	(1-7) Disagree-Agree				**-0.39**		
	My view is relaxing	(1-7) Disagree-Agree				**-0.32**		
	My view is distracting	(1-7) Disagree-Agree	**-0.14**				**-0.24**	
	My view is boring	(1-7) Disagree-Agree	**-0.23**	**-0.40**				
	I have a large size window view	(1-7) Very Small-Very Large			**-0.17**	**-0.59**		
	I have a view of the sky	(1-4) None-A lot			**-0.21**	**-0.63**		
	I have a view of trees	(1-4) None-A lot			**-0.24**	**-0.58**		
	I have a view of other plants	(1-4) None-A lot			**-0.23**	**-0.57**		
	I have a view of other buildings	(1-4) None-A lot				**-0.58**		
	I have a view of cars outside	(1-4) None-A lot				**-0.55**		
	I have a view of people outside	(1-4) None-A lot			**-0.18**	**-0.53**		
Lighting								
	I have no lighting problems	(0-1) No-Yes					**-0.16**	
	Lighting is just right	(1-7) Never-Always						
	Lighting is too bright	(1-7) Never-Always						
	Lighting is too dim	(1-7) Never-Always	**-0.20**					**-0.15**
	Lighting is too dull	(1-7) Never-Always	**-0.22**					
	There is not enough daylight	(0-1) No-Yes	**-0.31**	**-0.20**				**-0.16**
	There is too much daylight	(0-1) No-Yes				**-0.14**		
	There is not enough control of daylight	(0-1) No-Yes				**-0.15**		
	There is not enough electric light	(0-1) No-Yes			**-0.17**			
	There is not too much electric light	(0-1) No-Yes	**-0.13**	**-0.13**				
	There is not enough control of electric light	(0-1) No-Yes	**-0.14**					**-0.13**
	There is not enough sunlight	(0-1) No-Yes	**-0.24**	**-0.13**				
	There is too much sunlight	(0-1) No-Yes				**-0.18**		
	I am uncomfortable due to no task lights	(0-1) No-Yes						**-0.13**
	Reflections of electric lights bother me	(1-7) Never-Always	**-0.30**	**-0.17**			**-0.19**	**-0.22**
	Reflections of windows bother me	(1-7) Never-Always				**-0.30**		
	Reflections of skylights bother me	(1-7) Never-Always						
Thermal Comfort								
	I have no temperature problems	(0-1) No-Yes			**-0.18**			
	Temperature is too cold	(1-7) Never-Always					**-0.22**	
	Temperature is too hot	(1-7) Never-Always						
	My workspace is colder than other areas	(0-1) No-Yes						**-0.22**
	My workspace is hotter than other areas	(0-1) No-Yes						
	Air movement is too low	(0-1) No-Yes						
	The window is drafty	(0-1) No-Yes	**-0.14**					
	Incoming sun is uncomfortable	(0-1) No-Yes				**-0.13**		
	Heat from equipment is uncomfortable	(0-1) No-Yes						
Air Quality								
	Air is too stuffy	(1-7) Never-Always	**-0.13**					
	Air is too humid	(1-7) Never-Always						**-0.14**
	Air is too dry	(1-7) Never-Always	**-0.13**					
Acoustics								
	Noise level is noticable	(1-7) Never-Always						
	Noise level is distracting	(1-7) Never-Always						
	I wear headphones while working	(1-7) Never-Always						
	I keep a radio on while working	(1-7) Never-Always						**-0.12**
	I am distracted due to people talking	(0-1) No-Yes						
	I am distracted due to telephones ringing	(0-1) No-Yes			**-0.23**			
	Office equipment noise is noisy	(0-1) No-Yes	**-0.13**					
	Mechanical ventilation system is noisy	(0-1) No-Yes	**-0.26**					**-0.14**
	I am distracted by noise from office lights	(0-1) No-Yes	**-0.16**					
	I am distracted by noise from traffic	(0-1) No-Yes				**-0.26**		
	I am distracted by noise from consruction	(0-1) No-Yes						**-0.17**

Figure 14: <u>Negative</u> Pearson's correlations, questionnaire responses and physical measurements

			Health Problems					
Category	**Variable**	**Range**	**Difficulty Concentrating** (0-5) days	**Eye Strain** (0-5) days	**Fatigue** (0-5) days	**Headache** (0-5) days	**Common Cold** (0-5) days	**Flu** (0-5) days
View								
	My view is interesting	(1-7) Disagree-Agree						
	My view is realxing	(1-7) Disagree-Agree						
	My view is distracting	(1-7) Disagree-Agree						
	My view is boring	(1-7) Disagree-Agree	0.16		0.25	0.19		0.13
	I have a large size window view	(1-7) Very Small-Very Large						
	I have a view of the sky	(1-4) None-A lot						
	I have a view of trees	(1-4) None-A lot						
	I have a view of other plants	(1-4) None-A lot						
	I have a view of other buildings	(1-4) None-A lot						
	I have a view of cars outside	(1-4) None-A lot						
	I have a view of people outside	(1-4) None-A lot						
Lighting								
	Lighting is just right	(1-7) Never-Always						
	Lighting is too bright	(1-7) Never-Always	0.13					
	Lighting is too dim	(1-7) Never-Always		0.25	0.16	0.29		0.16
	Lighting is too glaring	(1-7) Never-Always				0.18		
	Lighting is too dull	(1-7) Never-Always		0.16	0.14	0.22		0.20
	I have no lighting problems	(0-1) No-Yes						
	There is not enough electric light	(0-1) No-Yes		0.15	0.15	0.14		
	There is too much electric light	(0-1) No-Yes	0.15	0.13				
	There is not enough control of electric light	(0-1) No-Yes	0.15	0.17	0.18	0.20		
	There is not enough daylight	(0-1) No-Yes	0.14	0.13	0.24	0.16		
	There is too much daylight	(0-1) No-Yes						
	There is not enough control of daylight	(0-1) No-Yes						0.19
	Reflections of electric lights bother me	(1-7) Never-Always	0.16	0.17	0.13	0.19		
	Reflections of windows bother me	(1-7) Never-Always	0.15					0.13
	Reflections of skylights bother me	(1-7) Never-Always					0.20	0.24
Thermal Comfort								
	Temperature is comfortable	(1-7) Never-Always						
	Temperature is too cold	(1-7) Never-Always						
	Temperature is too hot	(1-7) Never-Always		0.23		0.17	0.19	
	I have no temperature problems	(0-1) No-Yes						
	My workspace is hotter than other areas	(0-1) No-Yes		0.19		0.14	0.17	
	My workspace is colder than other areas	(0-1) No-Yes					0.15	
	My thermostat is inaccessable	(0-1) No-Yes	0.18	0.33		0.16	0.13	0.16
	Air movement is too low	(0-1) No-Yes		0.20	0.15	0.26	0.21	0.15
	Air from vents is uncomfortable	(0-1) No-Yes					0.15	
	The window is drafty	(0-1) No-Yes	0.27		0.13	0.15		0.15
Physical Measurements								
	Higher primary view factor	(0-4) None-High						
	Higher break view factor	(0-4) None-High						
	High daylight illuminance	(0-400) footcandles						
	I am below a skylight	(0-3) Away-Below						
	My desk is farther from an exterior wall	(6-60) feet		0.14				
	Temperature is high	(70.4-78.4) DegF						
Air Quality								
	Air quality is just right	(1-7) Never-Always						
	Air is too stuffy	(1-7) Never-Always	0.20	0.24		0.26	0.13	
	Air is too drafty	(1-7) Never-Always				0.14		
	Air is too humid	(1-7) Never-Always						
	Air is too dry	(1-7) Never-Always		0.29	0.21	0.31	0.24	0.17
Acoustics								
	Noise level is noticable	(1-7) Never-Always	0.23	0.15	0.14	0.22		
	Noise level is distracting	(1-7) Never-Always	0.34	0.15	0.18	0.23		
	I have no noise distractions	(0-1) No-Yes						
	Office equipment is noisy	(0-1) No-Yes	0.24	0.28	0.18			
	I am distracted by noise from office lights	(0-1) No-Yes						
	Construction noise is distracting	(0-1) No-Yes			0.17	0.14		0.13
Stairs Usage								
	I use the elevator more	(1-7) Never-<5 times a day			0.13	0.16		0.14
	I use the stairs more	(1-7) Never-<5 times a day						

Figure 15: <u>Positive</u> Pearson's correlations, questionnaire responses and health related symptoms reported

			Health Problems					
Category	**Variable**	**Range**	**Difficulty Concentrating** (0-5) days	**Eye Strain** (0-5) days	**Fatigue** (0-5) days	**Headache** (0-5) days	**Common Cold** (0-5) days	**Flu** (0-5) days
View								
	My view is interesting	(1-7) Disagree-Agree	**-0.20**	**-0.12**	**-0.27**	**-0.20**		**-0.15**
	My view is realxing	(1-7) Disagree-Agree	**-0.22**	**-0.21**	**-0.31**	**-0.20**		
	My view is distracting	(1-7) Disagree-Agree						
	My view is boring	(1-7) Disagree-Agree						
	I have a large size window view	(1-7) Very Small-Very Large		**-0.13**	**-0.22**	**-0.18**		
	I have a view of the sky	(1-4) None-A lot		**-0.13**	**-0.22**	**-0.20**		
	I have a view of trees	(1-4) None-A lot			**-0.22**	**-0.20**		
	I have a view of other plants	(1-4) None-A lot	**-0.13**	**-0.17**	**-0.26**	**-0.20**		
	I have a view of other buildings	(1-4) None-A lot		**-0.13**	**-0.19**	**-0.13**		
	I have a view of cars outside	(1-4) None-A lot	**-0.14**		**-0.23**	**-0.17**		
	I have a view of people outside	(1-4) None-A lot		**-0.14**	**-0.24**	**-0.19**		
Lighting								
	Lighting is just right	(1-7) Never-Always	**-0.27**	**-0.31**	**-0.25**	**-0.28**		**-0.19**
	Lighting is too bright	(1-7) Never-Always						
	Lighting is too dim	(1-7) Never-Always						
	Lighting is too glaring	(1-7) Never-Always						
	Lighting is too dull	(1-7) Never-Always						
	I have no lighting problems	(0-1) No-Yes	**-0.19**	**-0.22**	**-0.18**	**-0.14**		**-0.14**
	There is not enough electric light	(0-1) No-Yes						
	There is too much electric light	(0-1) No-Yes						
	There is not enough control of electric light	(0-1) No-Yes						
	There is not enough daylight	(0-1) No-Yes						
	There is too much daylight	(0-1) No-Yes						
	There is not enough control of daylight	(0-1) No-Yes						
	Reflections of electric lights bother me	(1-7) Never-Always						
	Reflections of windows bother me	(1-7) Never-Always						
	Reflections of skylights bother me	(1-7) Never-Always						
Thermal Comfort								
	Temperature is comfortable	(1-7) Never-Always		**-0.20**	**-0.22**	**-0.23**	**-0.14**	**-0.14**
	Temperature is too cold	(1-7) Never-Always						
	Temperature is too hot	(1-7) Never-Always						
	I have no temperature problems	(0-1) No-Yes	**-0.16**	**-0.20**	**-0.23**	**-0.27**	**-0.13**	
	My workspace is hotter than other areas	(0-1) No-Yes						
	My workspace is colder than other areas	(0-1) No-Yes						
	My thermostat is inaccessable	(0-1) No-Yes						
	Air movement is too low	(0-1) No-Yes						
	Air from vents is uncomfortable	(0-1) No-Yes						
	The window is drafty	(0-1) No-Yes						
Physical Measurements								
	Higher primary view factor	(0-4) None-High			**-0.15**			
	Higher break view factor	(0-4) None-High		**-0.13**	**-0.15**			
	High daylight illuminance	(0-400) footcandles						
	I am below a skylight	(0-3) Away-Below						
	My desk is farther from an exterior wall	(6-60) feet						
	Temperature is high	(70.4-78.4) DegF						
Air Quality								
	Air quality is just right	(1-7) Never-Always	**-0.16**	**-0.22**	**-0.25**	**-0.38**	**-0.18**	**-0.15**
	Air is too stuffy	(1-7) Never-Always						
	Air is too drafty	(1-7) Never-Always						
	Air is too humid	(1-7) Never-Always						
	Air is too dry	(1-7) Never-Always						
Acoustics								
	Noise level is noticable	(1-7) Never-Always						
	Noise level is distracting	(1-7) Never-Always						
	I have no noise distractions	(0-1) No-Yes	**-0.14**		**-0.16**	**-0.17**		
	Office equipment is noisy	(0-1) No-Yes						
	I am distracted by noise from office lights	(0-1) No-Yes						
	Construction noise is distracting	(0-1) No-Yes						
Stairs Usage								
	I use the elevator more	(1-7) Never-<5 times a day						
	I use the stairs more	(1-7) Never-<5 times a day		**-0.16**				**-0.19**

Figure 16: <u>Negative</u> Pearson's correlations, questionnaire responses and health related symptoms reported

			Stairs/Elevator Usage	
Category	**Variable**	**Range**	**Stairs used more** (0 to <5 times a day)	**Elevator used more** (0 to <5 times a day)
View				
	My view is interesting	(1-7) Disagree-Agree		
	My view is realxing	(1-7) Disagree-Agree		
	My view is distracting	(1-7) Disagree-Agree		
	My view is boring	(1-7) Disagree-Agree		
	I have a large size window view	(1-7) Very Small-Very Large		
	I have a view of the sky	(1-4) None-A lot		
	I have a view of trees	(1-4) None-A lot		
	I have a view of other plants	(1-4) None-A lot		
	I have a view of other buildings	(1-4) None-A lot		
	I have a view of cars outside	(1-4) None-A lot		
	I have a view of people outside	(1-4) None-A lot		
Lighting				
	Lighting is just right	(1-7) Never-Always		
	Lighting is too bright	(1-7) Never-Always		
	Lighting is too dim	(1-7) Never-Always		0.15
	Lighting is too glaring	(1-7) Never-Always		
	Lighting is too dull	(1-7) Never-Always		
	I have no lighting problems	(0-1) No-Yes		
	There is not enough electric light	(0-1) No-Yes		
	There is too much electric light	(0-1) No-Yes		
	There is not enough control of electric light	(0-1) No-Yes		
	There is not enough daylight	(0-1) No-Yes		
	There is too much daylight	(0-1) No-Yes		0.15
	There is not enough control of daylight	(0-1) No-Yes		
	Reflections of electric lights bother me	(1-7) Never-Always		
	Reflections of windows bother me	(1-7) Never-Always		0.13
	Reflections of skylights bother me	(1-7) Never-Always		
Thermal Comfort				
	Temperature is comfortable	(1-7) Never-Always		
	Temperature is too cold	(1-7) Never-Always		
	Temperature is too hot	(1-7) Never-Always		0.21
	I have no temperature problems	(0-1) No-Yes		
	My workspace is hotter than other areas	(0-1) No-Yes		0.14
	My workspace is colder than other areas	(0-1) No-Yes		0.16
	My thermostat is inaccessable	(0-1) No-Yes		
	Air movement is too low	(0-1) No-Yes		
	Air from vents is uncomfortable	(0-1) No-Yes		
	The window is drafty	(0-1) No-Yes		
Physical Measurements				
	Higher primary view factor	(0-4) None-High		
	Higher break view factor	(0-4) None-High		
	High daylight illuminance	(0-400) footcandles		
	I am below a skylight	(0-3) Away-Below		
	My desk is farther from an exterior wall	(6-60) feet		
	Temperature is high	(70.4-78.4) DegF		
Air Quality				
	Air quality is just right	(1-7) Never-Always		
	Air is too stuffy	(1-7) Never-Always		
	Air is too drafty	(1-7) Never-Always		
	Air is too humid	(1-7) Never-Always		
	Air is too dry	(1-7) Never-Always		
Acoustics				
	Noise level is noticable	(1-7) Never-Always		
	Noise level is distracting	(1-7) Never-Always		
	I have no noise distractions	(0-1) No-Yes	0.12	
	Office equipment is noisy	(0-1) No-Yes		
	I am distracted by noise from office lights	(0-1) No-Yes		
	Construction noise is distracting	(0-1) No-Yes		
Stairs Usage				
	I use the elevator more	(1-7) Never-<5 times a day		
	I use the stairs more	(1-7) Never-<5 times a day		

Figure 17: <u>Positive</u> Pearson's correlations, questionnaire responses and stairs/elevator usage reported

Category	Variable	Range	Stairs/Elevator Usage: Stairs used less (0 to <5 times a day)	Stairs/Elevator Usage: Elevator used les (0 to <5 times a day)
View				
	My view is interesting	(1-7) Disagree-Agree		
	My view is realxing	(1-7) Disagree-Agree		
	My view is distracting	(1-7) Disagree-Agree		
	My view is boring	(1-7) Disagree-Agree		
	I have a large size window view	(1-7) Very Small-Very Large		
	I have a view of the sky	(1-4) None-A lot		
	I have a view of trees	(1-4) None-A lot		
	I have a view of other plants	(1-4) None-A lot		
	I have a view of other buildings	(1-4) None-A lot		
	I have a view of cars outside	(1-4) None-A lot		
	I have a view of people outside	(1-4) None-A lot		
Lighting				
	Lighting is just right	(1-7) Never-Always		**-0.17**
	Lighting is too bright	(1-7) Never-Always		
	Lighting is too dim	(1-7) Never-Always		
	Lighting is too glaring	(1-7) Never-Always		
	Lighting is too dull	(1-7) Never-Always		
	I have no lighting problems	(0-1) No-Yes		
	There is not enough electric light	(0-1) No-Yes		
	There is too much electric light	(0-1) No-Yes		
	There is not enough control of electric light	(0-1) No-Yes		
	There is not enough daylight	(0-1) No-Yes		
	There is too much daylight	(0-1) No-Yes		
	There is not enough control of daylight	(0-1) No-Yes		
	Reflections of electric lights bother me	(1-7) Never-Always		
	Reflections of windows bother me	(1-7) Never-Always		
	Reflections of skylights bother me	(1-7) Never-Always	**-0.13**	
Thermal Comfort				
	Temperature is comfortable	(1-7) Never-Always		
	Temperature is too cold	(1-7) Never-Always		
	Temperature is too hot	(1-7) Never-Always		
	I have no temperature problems	(0-1) No-Yes		
	My workspace is hotter than other areas	(0-1) No-Yes		
	My workspace is colder than other areas	(0-1) No-Yes		
	My thermostat is inaccessable	(0-1) No-Yes		
	Air movement is too low	(0-1) No-Yes		
	Air from vents is uncomfortable	(0-1) No-Yes		
	The window is drafty	(0-1) No-Yes		
Physical Measurements				
	Higher primary view factor	(0-4) None-High		
	Higher break view factor	(0-4) None-High		
	High daylight illuminance	(0-400) footcandles	**-0.18**	
	I am below a skylight	(0-3) Away-Below		
	My desk is farther from an exterior wall	(6-60) feet		
	Temperature is high	(70.4-78.4) DegF	**-0.20**	
Air Quality				
	Air quality is just right	(1-7) Never-Always		
	Air is too stuffy	(1-7) Never-Always		
	Air is too drafty	(1-7) Never-Always		
	Air is too humid	(1-7) Never-Always		
	Air is too dry	(1-7) Never-Always		
Acoustics				
	Noise level is noticable	(1-7) Never-Always		
	Noise level is distracting	(1-7) Never-Always		
	I have no noise distractions	(0-1) No-Yes		
	Office equipment is noisy	(0-1) No-Yes		
	I am distracted by noise from office lights	(0-1) No-Yes		
	Construction noise is distracting	(0-1) No-Yes		
Stairs Usage				
	I use the elevator more	(1-7) Never-<5 times a day	**-0.37**	
	I use the stairs more	(1-7) Never-<5 times a day		**-0.37**

Figure 18: <u>Negative</u> Pearson's correlations, questionnaire responses and stairs/elevator usage reported

3. SMUD PHOTO-TOUR

3.1 Customer Service Center Building (CSC)

Figure 19: CSC exterior views
– Southwest wing (left) and view the west orientation (right)

The CSC building is the latest addition to the SMUD campus and has been in operation since 1995. The CSC building is composed of four wings oriented along the east–west axis. The southwest wing houses the customer call center, while the other wings house the other administrative departments. Each wing has windows facing south and north, with the south windows well shaded by overhangs, and north windows relatively unshaded. The top floors have skylights in addition to windows.

Figure 20: Interior views - South Windows (left) and North Windows (right)

The interiors feature modern direct/indirect suspended light fixtures that are also capable of dimming based on the available daylighting levels. The south windows are well shaded in all the spaces by external overhangs. In addition some spaces

also have internal light-shelves that reflect more light up onto the ceiling and help distribute the light further into the space. The north windows are more expansive and have relatively none shading from external shading devices. Both the north and south windows have vertical blinds on the interior and also have operable windows.

The floor plan is divided into individual workstations that feature light colors; low partitions for good visibility and floor based air delivery system that is operable by the occupants.

Figure 21: Interior views – Skylights

The top floors of the four wings have skylights in addition to the north and south windows. The skylights are integrated with the electric lighting systems through the use of automated dimming controls on the electric light fixtures. The skylights also have motorized louvers that are actuated to prevent excessive sun penetration and glare.

3.2 Headquarters Building (HQ)

Figure 22: HQ exterior views – South wing (left) and north wing (right)

The headquarters building is the oldest of the three buildings studied in this research project. The building is composed of two wings – the north wing and the south wing. The North wing has a square floor plate while the south wing has a rectangular floor plate. The entire wall surface is composed of dark tinted windows, and there are movable louvers on the exterior of the south, east and west windows. Currently, only the east and west windows have operable louvers.

Figure 23: Interior views of the HQ building

The interior shows a low ceiling with recessed fluorescent lighting fixtures. Half of the lighting fixtures have been de-lamped as part of SMUD's energy efficiency measures. The window glass has a dark tint and does not let in any significant amount of daylight into the space in spite of the high window/wall area ratio. The air delivery is through a conventional duct based system in the plenum.

3.3 59th St. Distribution Service Building (DS)

Figure 24: Exterior view of DS building

The DS building is the smallest of the three buildings with two floors, and a single building with rectangular floor plate. The study included only the top (2nd) floor of

the building. The building has the least window area of the three buildings, and the windows are covered with an exterior shade screen that blocks view of the windows.

Figure 25: Interior views of DS building
– view of shade screen (left) and typical cubicle view (right)

The interior shows a recessed fluorescent lighting system with a low ceiling. There is minimal daylight penetration in the space from the windows due to the shade screens.

The interiors have been recently retrofitted with new task lights, new cubicles and wall finishes.

4. SURVEY FORMS

In this section the survey forms used by the researchers during site visits are documented.

4.1 Light level readings

The following form was used to collect horizontal light levels at the desk level and near the data loggers using a handheld illuminance meter.

0012- Office Workspace Study **Surveyor**

Baseline Lighting levels **Survey Date**

Space ID# page

ID#	Location	Horiz Light readings (foot-candles)			
		Blinds : _____ Lights: _____ Start Time: _____ End Time: _____	Blinds : _____ Lights: _____ Start Time: _____ End Time: _____	Blinds : _____ Lights: _____ Start Time: _____ End Time: _____	Blinds : _____ Lights: _____ Start Time: _____ End Time: _____

Figure 26: Horizontal Light Level Readings Data Collection Form

A similar data collection form was generated to collect cubic illuminance measurements at each workstation, where we collected both horizontal and vertical light level readings with a handheld illuminance meter.

0012- Office Workspace Study
Baseline Lighting levels
Space ID# Call Center

Surveyor
Survey Date
Survey Time

Blinds State
Lights

Page

ID#	Location	Light readings (foot-candles)					
		Up	Down	Vertical			
				S	W	N	E

Figure 27: Cubic Illumination Level Readings Data Collection Form

4.2 Cubicle Specific Information

We collected data on the physical characteristics of the cubicles such as orientation, floor register status, # fans, partition heights etc. which varied between cubicles through visual observations.

0012- Office Workspace Study
Cubicle Information
Space ID# CSC South-West 2nd floor

Surveyor
Survey Date
Survey Time
page 1 of 1

Last Name	First initial	Cubicle #	Chair Orientation	Floor register status (1-4)	# Task Lights	# Fans	Partition heights		Comments
				1= closed, 2= slightly open, 3=50% or more open, 4= Open			L= low, H= high, W=wall		

Figure 28: Cubicle Physical Characteristics Data Collection Form

Similarly we collected data on the quality of view from each cubicle by visual observation of the primary view (view when facing the task surface) and break view (view when turned away from task).

0012- Office Workspace Study

Cubicle View Factors

Space ID# CSC South-West 2nd floor

Last Name	First initial	Cubicle #	Glare (Y/N)	View Factor (0-5)	Window Orientation	Window# 1	Break view factor (0-5)	Window Orientation	Window# 1	Clearstory (Y/N)	Photos

Figure 29: Cubicle View Rating Data Collection Form

4.3 Blinds Usage Monitoring

A surveyor from HMG observed the blind positions on each of the blinds in the Call center using a standardized data collection form.

0012- Office Workspace Study
Blinds use monitoring form
Space ID# Call Center

Surveyor
Survey Date
Survey Time

	Blind Angle					% drawn					Window		
	1	2	3	4	5	1	2	3	4	5	Open?		
Blind #	*Closed*	*slightly open*	*45 deg left*	*45 deg right*	*Open*	100%	< 50%	50%	> 50%	0%	left	middle	right
N-view1a	○	○	○	○	○	○	○	○	○	○	○	○	○
N-view1b	○	○	○	○	○	○	○	○	○	○	○	○	○
N-view2a	○	○	○	○	○	○	○	○	○	○	○	○	○
N-view2b	○	○	○	○	○	○	○	○	○	○	○	○	○
N-view3a	○	○	○	○	○	○	○	○	○	○	○	○	○
N-view3b	○	○	○	○	○	○	○	○	○	○	○	○	○
N-view4a	○	○	○	○	○	○	○	○	○	○	○	○	○
N-view4b	○	○	○	○	○	○	○	○	○	○	○	○	○
N-view5a	○	○	○	○	○	○	○	○	○	○	○	○	○
N-view5b	○	○	○	○	○	○	○	○	○	○	○	○	○
N-view6a	○	○	○	○	○	○	○	○	○	○	○	○	○
N-view6b	○	○	○	○	○	○	○	○	○	○	○	○	○
N-view7a	○	○	○	○	○	○	○	○	○	○	○	○	○
N-view7b	○	○	○	○	○	○	○	○	○	○	○	○	○
N-view8a	○	○	○	○	○	○	○	○	○	○	○	○	○
N-view8b	○	○	○	○	○	○	○	○	○	○	○	○	○
N-view9a	○	○	○	○	○	○	○	○	○	○	○	○	○
N-view9b	○	○	○	○	○	○	○	○	○	○	○	○	○

Figure 30: Blind Position Observation Form

4.4 Logger Database

The surveyors maintained a database of all the lighting and temperature loggers installed in the three buildings, with information on their location, installation time, time of data download as well as the logger serial numbers.

0012- Office Workspace Study
Logger Database
Space ID#

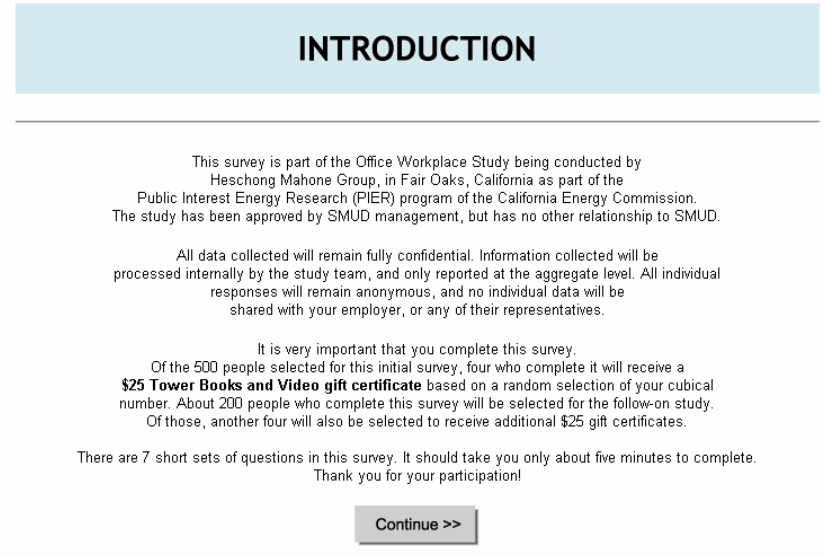
Surveyor
Survey Date
Survey Time

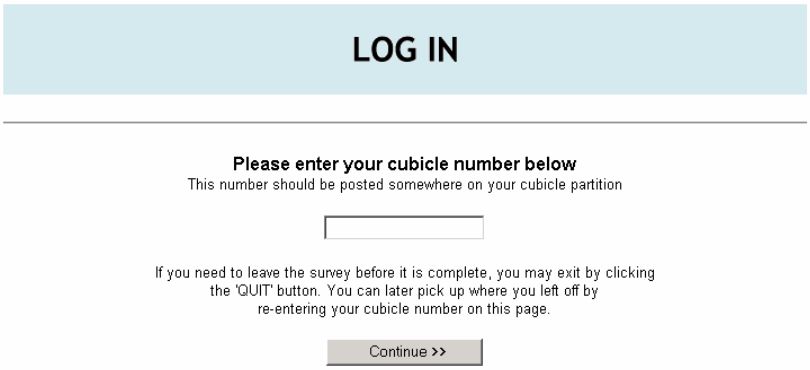
Logger Type	Logger #	Location code	nearest cubicle #'s	Installation		Data Download 1		Data Download 2	
				Date	Time	Date	Time	Date	Time
see code below	number written on logger	number written on drawings							

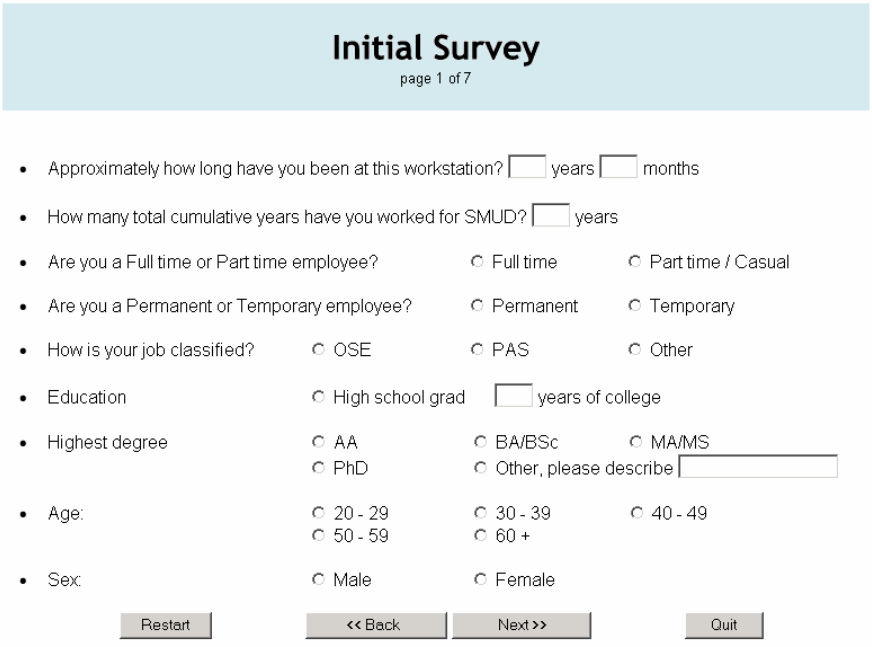
Figure 31: Data Logger Database Form

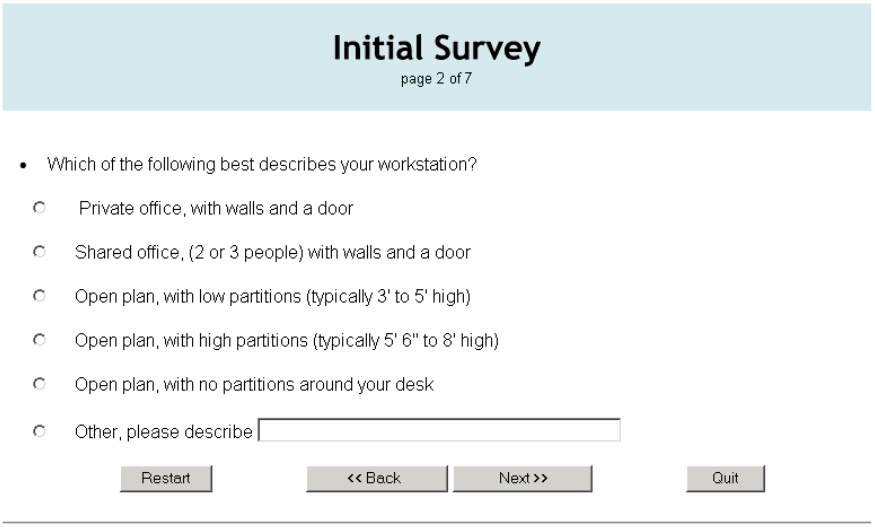
5. INITIAL SURVEY – SCREEN SHOTS

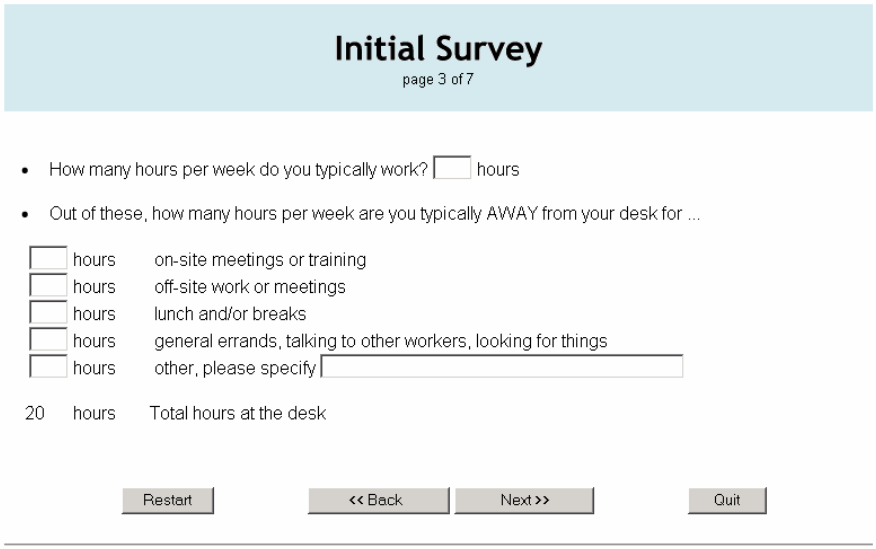
In this section, screen-shots of the computer-based Initial Survey are presented.

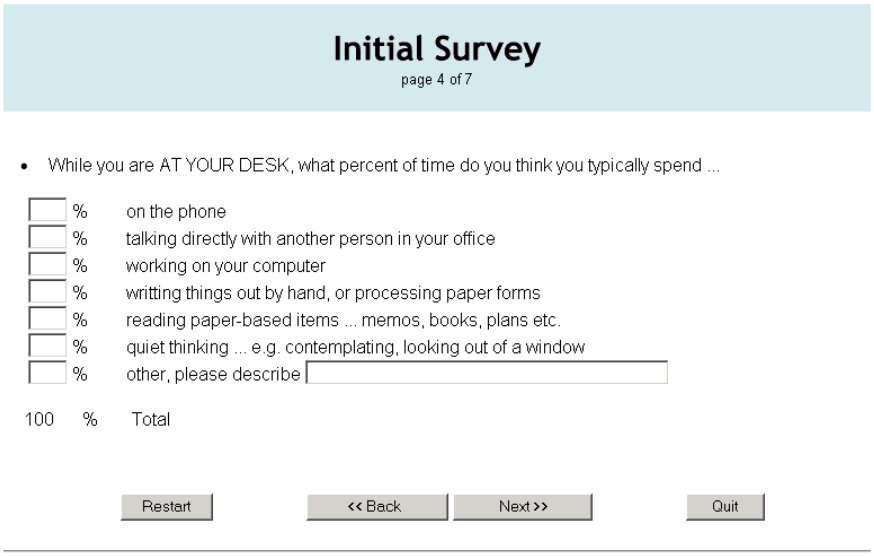



LOG IN
Please enter your cubicle number below
This number should be posted somewhere on your cubicle partition
If you need to leave the survey before it is complete, you may exit by clicking the 'QUIT' button. You can later pick up where you left off by re-entering your cubicle number on this page.
Continue >>


Initial Survey
page 1 of 7
Approximately how long have you been at this workstation? years months
How many total cumulative years have you worked for SMUD? years
Are you a Full time or Part time employee? Full time Part time / Casual
Are you a Permanent or Temporary employee? Permanent Temporary
How is your job classified? OSE PAS Other
Education High school grad years of college
Highest degree AA BA/BSc MA/MS PhD Other, please describe
Age: 20 - 29 30 - 39 40 - 49 50 - 59 60 +
Sex: Male Female
Restart
<< Back
Next >>
Quit


Initial Survey
page 2 of 7
Which of the following best describes your workstation?
Private office, with walls and a door
Shared office, (2 or 3 people) with walls and a door
Open plan, with low partitions (typically 3' to 5' high)
Open plan, with high partitions (typically 5' 6" to 8' high)
Open plan, with no partitions around your desk
Other, please describe
Restart
<< Back
Next >>
Quit


Initial Survey
page 3 of 7
How many hours per week do you typically work? hours
Out of these, how many hours per week are you typically AWAY from your desk for ...
hours on-site meetings or training
hours off-site work or meetings
hours lunch and/or breaks
hours general errands, talking to other workers, looking for things
hours other, please specify
20 hours Total hours at the desk
Restart
<< Back
Next >>
Quit



Initial Survey

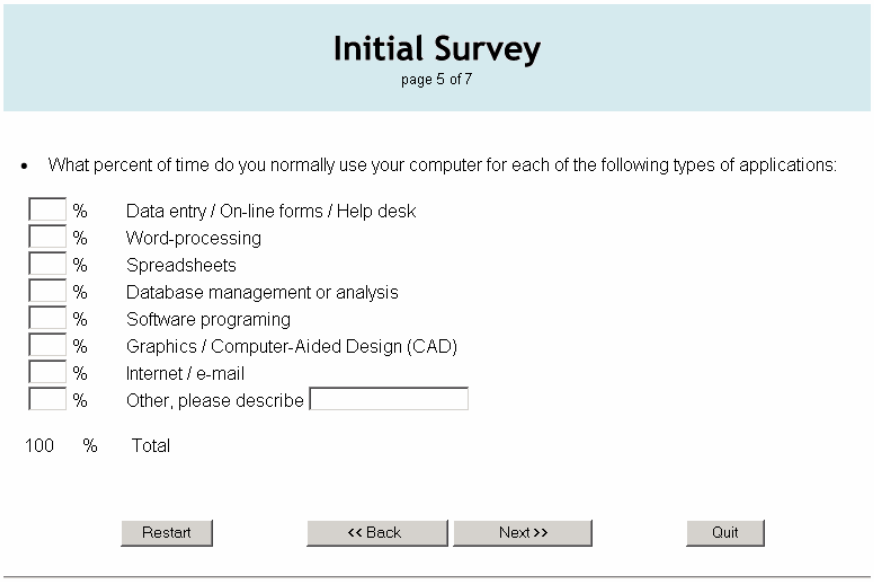
page 4 of 7

- While you are AT YOUR DESK, what percent of time do you think you typically spend ...

☐	%	on the phone
☐	%	talking directly with another person in your office
☐	%	working on your computer
☐	%	writting things out by hand, or processing paper forms
☐	%	reading paper-based items ... memos, books, plans etc.
☐	%	quiet thinking ... e.g. contemplating, looking out of a window
☐	%	other, please describe ☐

100 % Total

Restart << Back Next >> Quit



Initial Survey

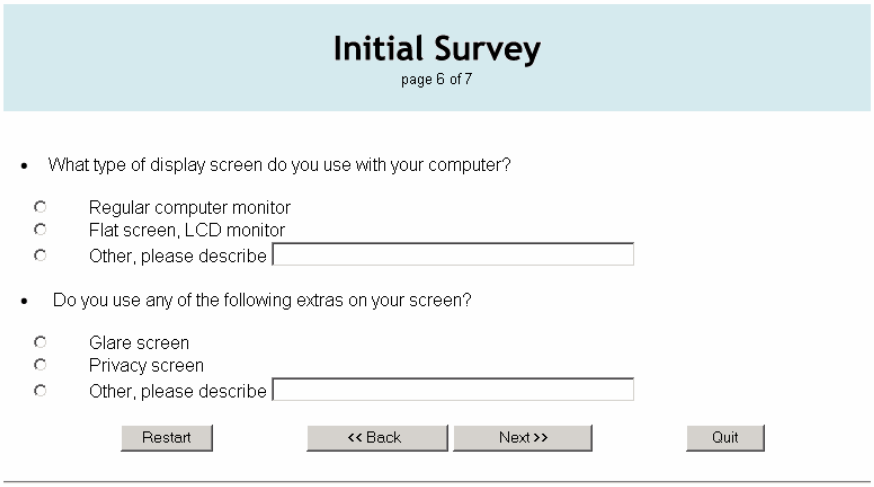
page 5 of 7

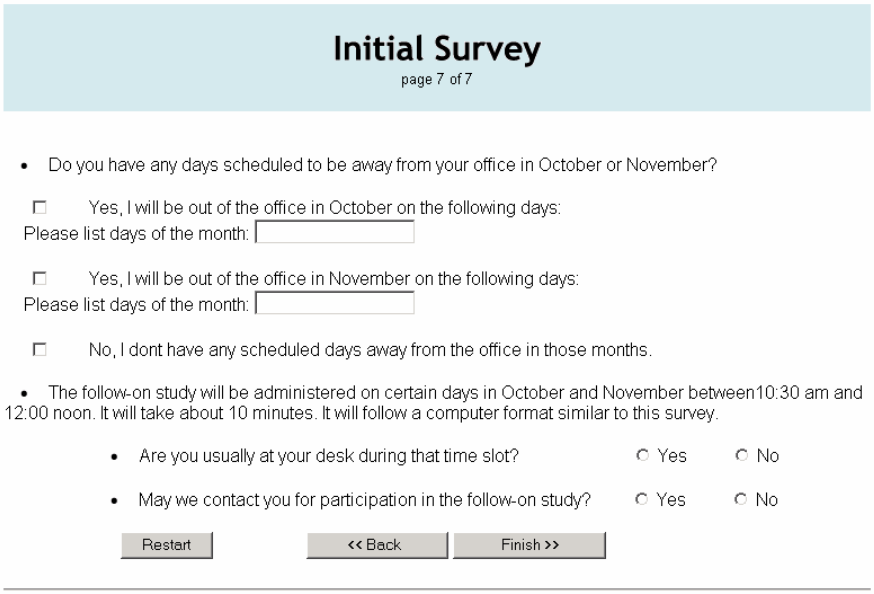
- What percent of time do you normally use your computer for each of the following types of applications:

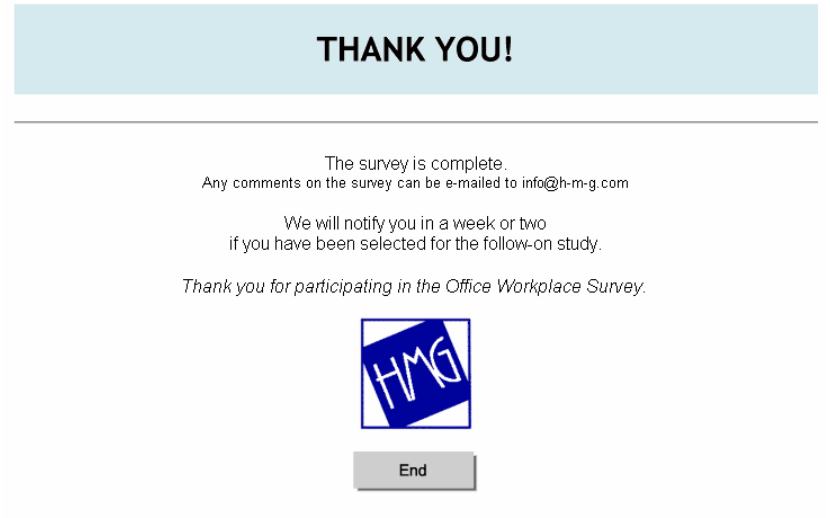
☐	%	Data entry / On-line forms / Help desk
☐	%	Word-processing
☐	%	Spreadsheets
☐	%	Database management or analysis
☐	%	Software programing
☐	%	Graphics / Computer-Aided Design (CAD)
☐	%	Internet / e-mail
☐	%	Other, please describe ☐

100 % Total

Restart << Back Next >> Quit

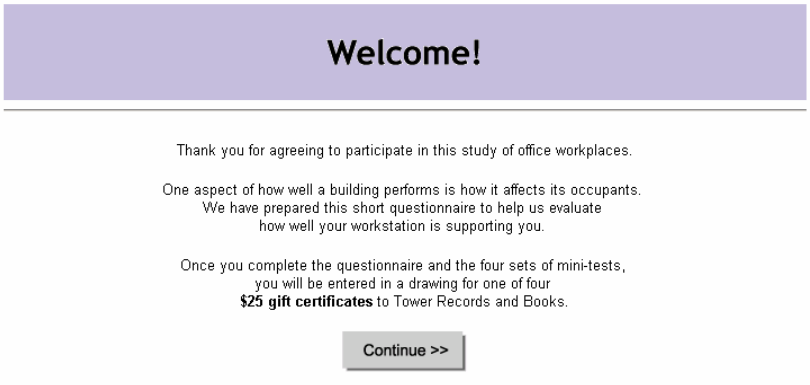

Initial Survey
page 6 of 7
What type of display screen do you use with your computer?
Regular computer monitor
Flat screen, LCD monitor
Other, please describe
Do you use any of the following extras on your screen?
Glare screen
Privacy screen
Other, please describe
Restart
<< Back
Next >>
Quit

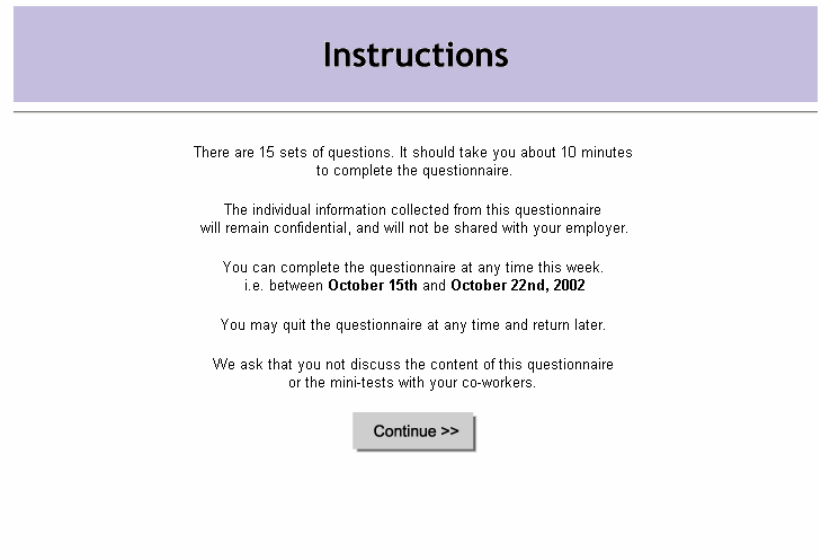

Initial Survey
page 7 of 7
Do you have any days scheduled to be away from your office in October or November?
Yes, I will be out of the office in October on the following days:
Please list days of the month:
Yes, I will be out of the office in November on the following days:
Please list days of the month:
No, I dont have any scheduled days away from the office in those months.
The follow-on study will be administered on certain days in October and November between10:30 am and 12:00 noon. It will take about 10 minutes. It will follow a computer format similar to this survey.
Are you usually at your desk during that time slot? Yes No
May we contact you for participation in the follow-on study? Yes No
Restart
<< Back
Finish >>


THANK YOU!
The survey is complete.
Any comments on the survey can be e-mailed to info@h-m-g.com
We will notify you in a week or two
if you have been selected for the follow-on study.
Thank you for participating in the Office Workplace Survey.
HMG
End

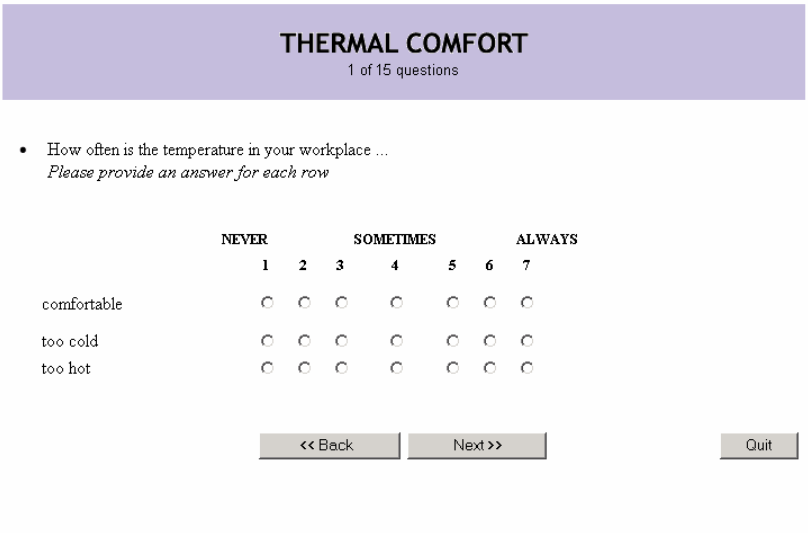
6. QUESTIONNAIRE – SCREEN SHOTS

In this section, screen-shots of the computer-based Questionnaire is presented.




Instructions
There are 15 sets of questions. It should take you about 10 minutes to complete the questionnaire.
The individual information collected from this questionnaire will remain confidential, and will not be shared with your employer.
You can complete the questionnaire at any time this week. i.e. between October 15th and October 22nd, 2002
You may quit the questionnaire at any time and return later.
We ask that you not discuss the content of this questionnaire or the mini-tests with your co-workers.
Continue >>


LOG IN
Please enter your cubicle number below
This number should be posted somewhere on your cubicle partition
If you need to leave the survey before it is complete, you may exit by clicking the 'QUIT' button. You can later pick up where you left off by re-entering your cubicle number on this page.
Continue >>

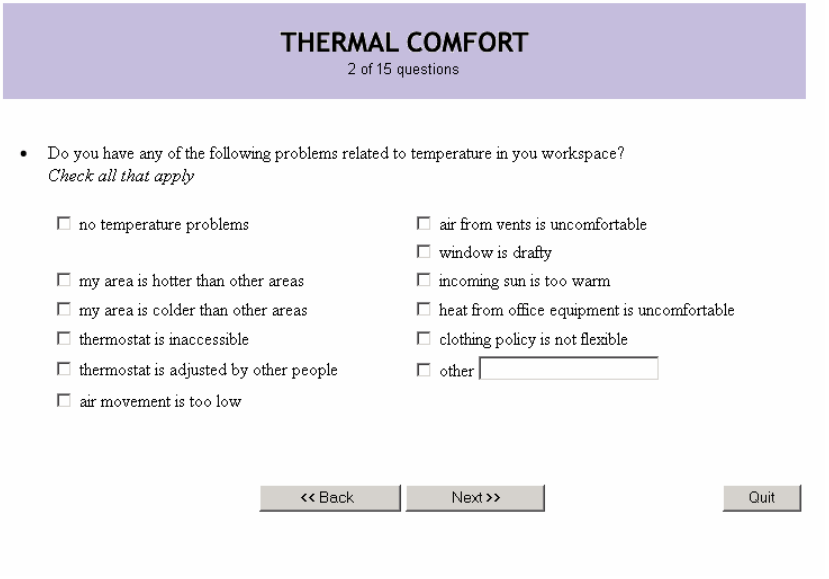


THERMAL COMFORT
1 of 15 questions

- How often is the temperature in your workplace ...
  Please provide an answer for each row

	NEVER			SOMETIMES			ALWAYS
	1	2	3	4	5	6	7
comfortable	○	○	○	○	○	○	○
too cold	○	○	○	○	○	○	○
too hot	○	○	○	○	○	○	○

<< Back | Next >> | Quit

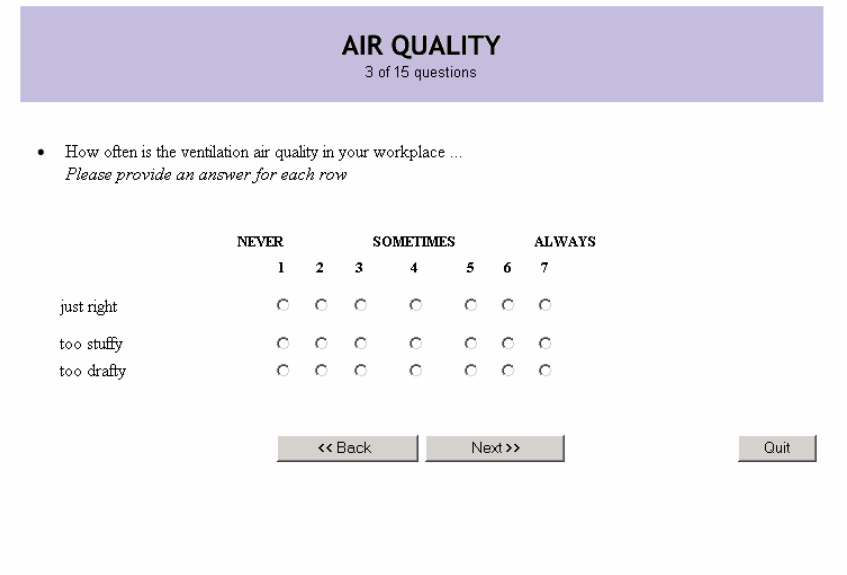


THERMAL COMFORT
2 of 15 questions

- Do you have any of the following problems related to temperature in you workspace?
  Check all that apply

- ☐ no temperature problems
- ☐ my area is hotter than other areas
- ☐ my area is colder than other areas
- ☐ thermostat is inaccessible
- ☐ thermostat is adjusted by other people
- ☐ air movement is too low
- ☐ air from vents is uncomfortable
- ☐ window is drafty
- ☐ incoming sun is too warm
- ☐ heat from office equipment is uncomfortable
- ☐ clothing policy is not flexible
- ☐ other

<< Back | Next >> | Quit

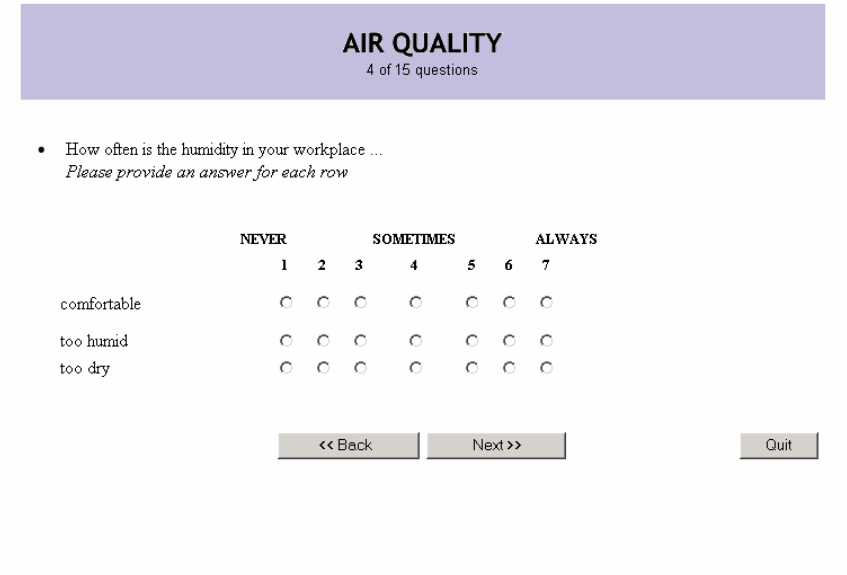


AIR QUALITY
3 of 15 questions

- How often is the ventilation air quality in your workplace ...
  Please provide an answer for each row

	NEVER			SOMETIMES			ALWAYS
	1	2	3	4	5	6	7
just right	○	○	○	○	○	○	○
too stuffy	○	○	○	○	○	○	○
too drafty	○	○	○	○	○	○	○

<< Back Next >> Quit

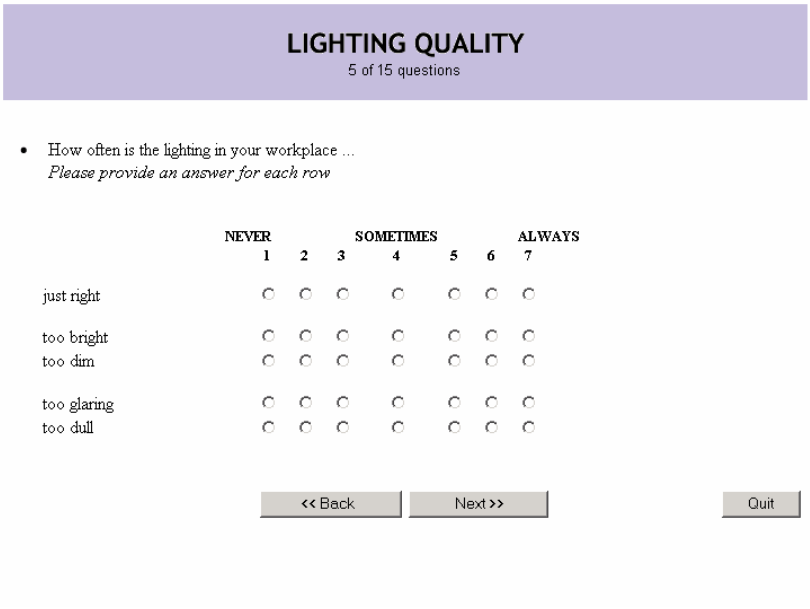


AIR QUALITY
4 of 15 questions

- How often is the humidity in your workplace ...
  Please provide an answer for each row

	NEVER			SOMETIMES			ALWAYS
	1	2	3	4	5	6	7
comfortable	○	○	○	○	○	○	○
too humid	○	○	○	○	○	○	○
too dry	○	○	○	○	○	○	○

<< Back Next >> Quit



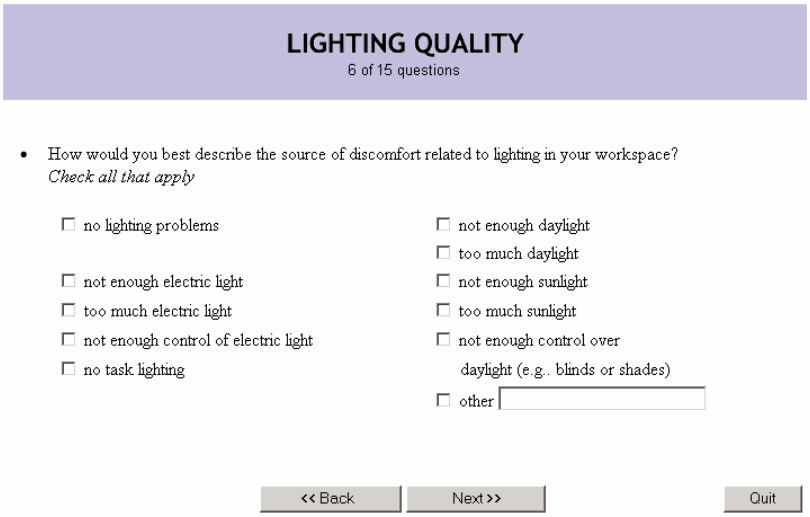
LIGHTING QUALITY

5 of 15 questions

- How often is the lighting in your workplace ...
  Please provide an answer for each row

	NEVER 1	2	3	4	5	6	ALWAYS 7
just right	○	○	○	○	○	○	○
too bright	○	○	○	○	○	○	○
too dim	○	○	○	○	○	○	○
too glaring	○	○	○	○	○	○	○
too dull	○	○	○	○	○	○	○

<< Back | Next >> | Quit



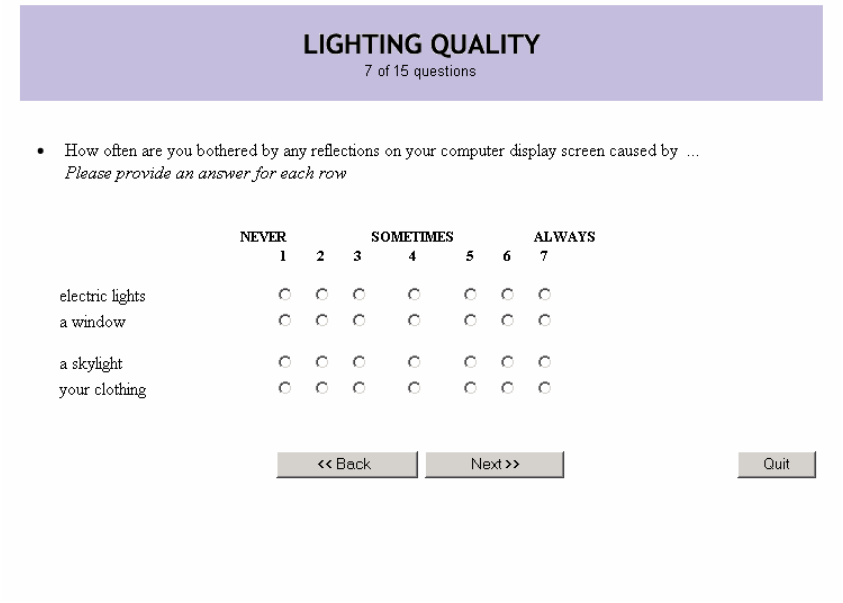
LIGHTING QUALITY

6 of 15 questions

- How would you best describe the source of discomfort related to lighting in your workspace?
  Check all that apply

- ☐ no lighting problems
- ☐ not enough electric light
- ☐ too much electric light
- ☐ not enough control of electric light
- ☐ no task lighting
- ☐ not enough daylight
- ☐ too much daylight
- ☐ not enough sunlight
- ☐ too much sunlight
- ☐ not enough control over daylight (e.g.. blinds or shades)
- ☐ other

<< Back | Next >> | Quit

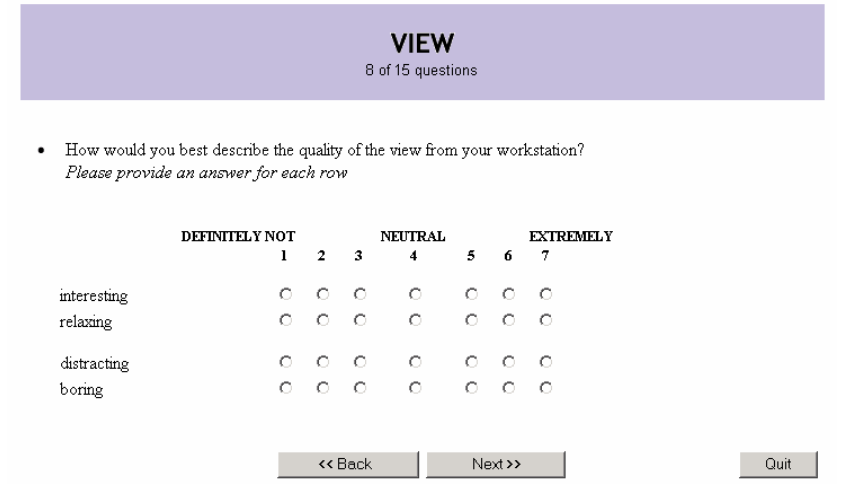


LIGHTING QUALITY
7 of 15 questions

- How often are you bothered by any reflections on your computer display screen caused by …
  Please provide an answer for each row

	NEVER 1	2	3	SOMETIMES 4	5	6	ALWAYS 7
electric lights	○	○	○	○	○	○	○
a window	○	○	○	○	○	○	○
a skylight	○	○	○	○	○	○	○
your clothing	○	○	○	○	○	○	○

<< Back Next >> Quit

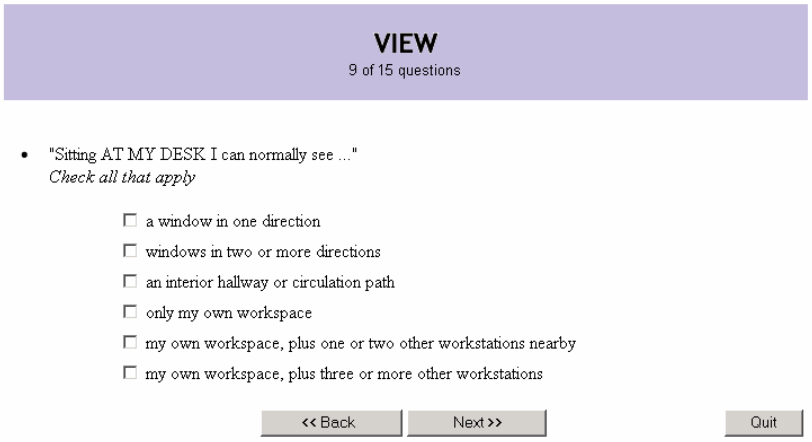


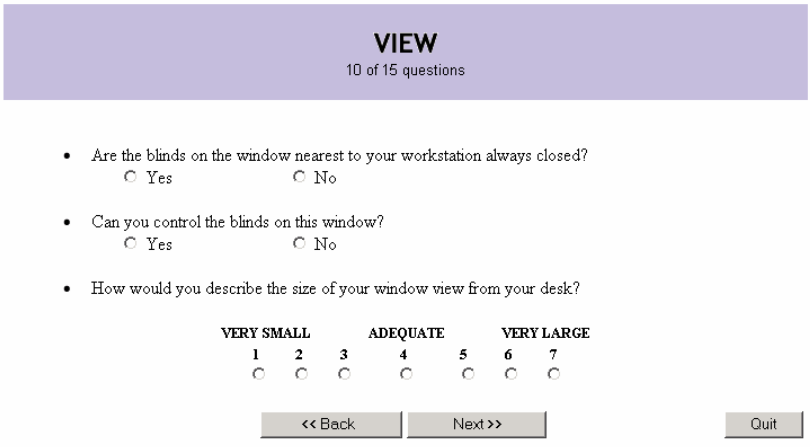
VIEW
8 of 15 questions

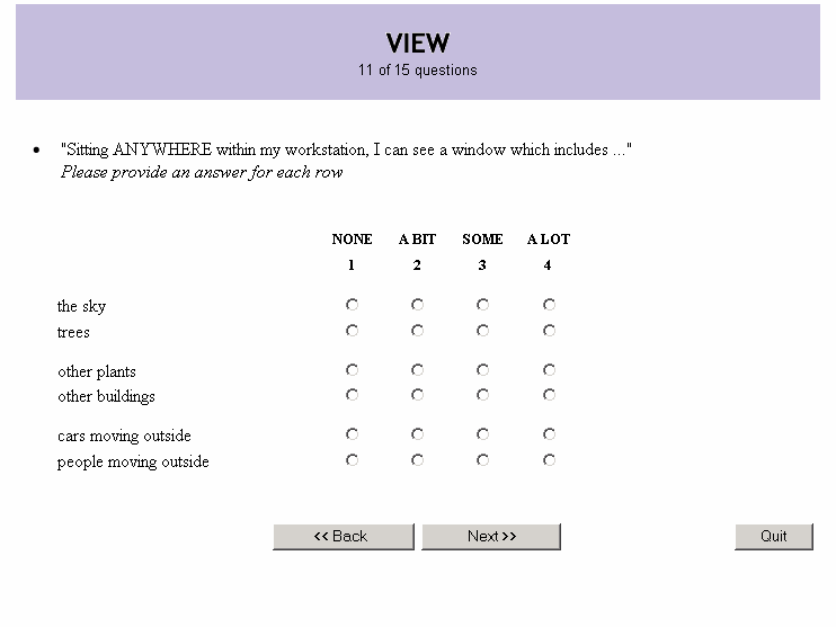
- How would you best describe the quality of the view from your workstation?
  Please provide an answer for each row

	DEFINITELY NOT 1	2	3	NEUTRAL 4	5	6	EXTREMELY 7
interesting	○	○	○	○	○	○	○
relaxing	○	○	○	○	○	○	○
distracting	○	○	○	○	○	○	○
boring	○	○	○	○	○	○	○

<< Back Next >> Quit


VIEW
9 of 15 questions
"Sitting AT MY DESK I can normally see ..."
Check all that apply
a window in one direction
windows in two or more directions
an interior hallway or circulation path
only my own workspace
my own workspace, plus one or two other workstations nearby
my own workspace, plus three or more other workstations
<< Back
Next >>
Quit


VIEW
10 of 15 questions
Are the blinds on the window nearest to your workstation always closed?
Yes
No
Can you control the blinds on this window?
Yes
No
How would you describe the size of your window view from your desk?
VERY SMALL
ADEQUATE
VERY LARGE
1 2 3 4 5 6 7
<< Back
Next >>
Quit

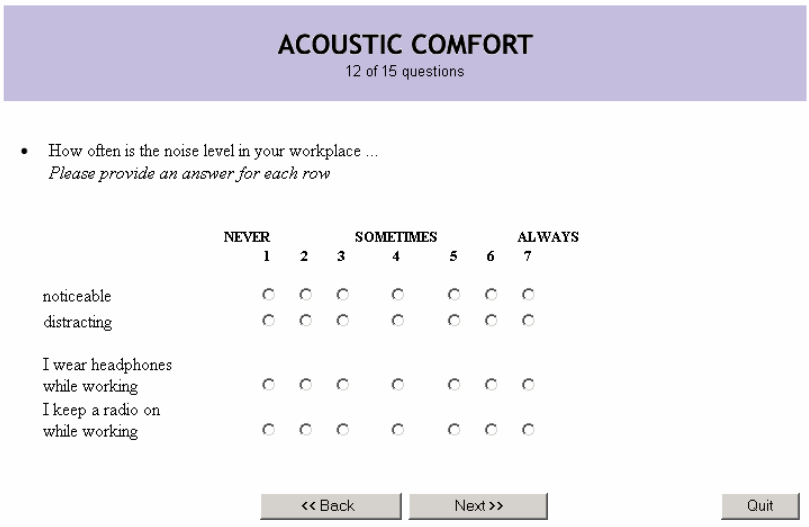


VIEW
11 of 15 questions

- "Sitting ANYWHERE within my workstation, I can see a window which includes ..."
  Please provide an answer for each row

	NONE 1	A BIT 2	SOME 3	A LOT 4
the sky	○	○	○	○
trees	○	○	○	○
other plants	○	○	○	○
other buildings	○	○	○	○
cars moving outside	○	○	○	○
people moving outside	○	○	○	○

<< Back Next >> Quit

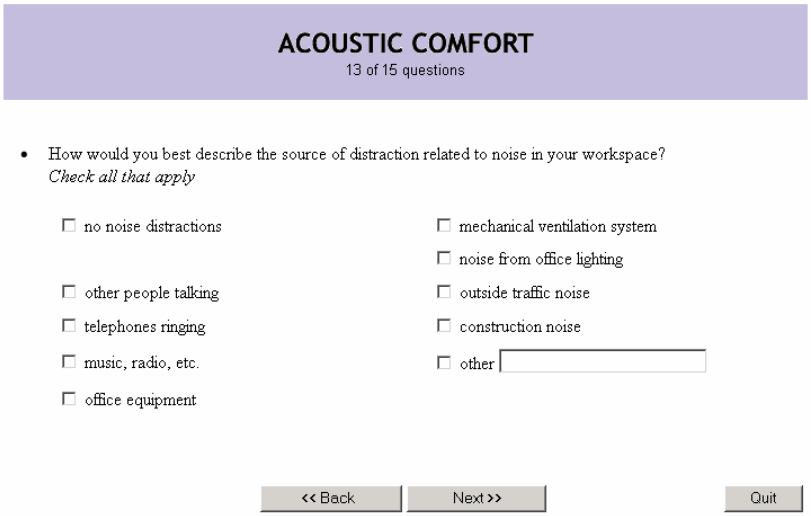


ACOUSTIC COMFORT
12 of 15 questions

- How often is the noise level in your workplace ...
  Please provide an answer for each row

	NEVER 1	2	3	SOMETIMES 4	5	6	ALWAYS 7
noticeable	○	○	○	○	○	○	○
distracting	○	○	○	○	○	○	○
I wear headphones while working	○	○	○	○	○	○	○
I keep a radio on while working	○	○	○	○	○	○	○

<< Back Next >> Quit

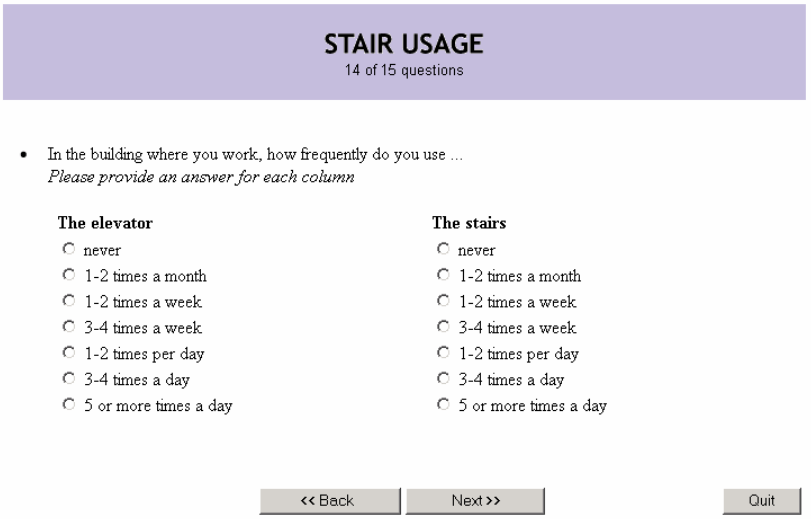


ACOUSTIC COMFORT
13 of 15 questions

- How would you best describe the source of distraction related to noise in your workspace?
  Check all that apply

☐ no noise distractions
☐ other people talking
☐ telephones ringing
☐ music, radio, etc.
☐ office equipment
☐ mechanical ventilation system
☐ noise from office lighting
☐ outside traffic noise
☐ construction noise
☐ other

<< Back | Next >> | Quit



STAIR USAGE
14 of 15 questions

- In the building where you work, how frequently do you use ...
  Please provide an answer for each column

The elevator	The stairs
○ never	○ never
○ 1-2 times a month	○ 1-2 times a month
○ 1-2 times a week	○ 1-2 times a week
○ 3-4 times a week	○ 3-4 times a week
○ 1-2 times per day	○ 1-2 times per day
○ 3-4 times a day	○ 3-4 times a day
○ 5 or more times a day	○ 5 or more times a day

<< Back | Next >> | Quit

GENERAL HEALTH

15 of 15 questions

- Were you bothered by any of the following health related symptoms in the past week (i.e. past five working days)?
  Please provide the number of days for each symptom that applies

☐ days	headache	☐ days	common cold symptoms
☐ days	migraine	☐ days	allergy symptoms
☐ days	neck or shoulder ache	☐ days	asthma symptoms
☐ days	back ache or joint aches	☐ days	eye strain, dry or itchy eyes
☐ days	fatigue	☐ days	stomach upset
☐ days	difficulty concentrating	☐ days	high stress level
☐ days	flu symptoms	☐ days	other ☐

<< Back | Next >> | Quit

THANK YOU!

The questionnaire is complete.
If you wish, you may review and/or change your answers in the questionnaire by clicking on the 'Review' button.

Instructions for the first Mini-Test will be sent to you next week.

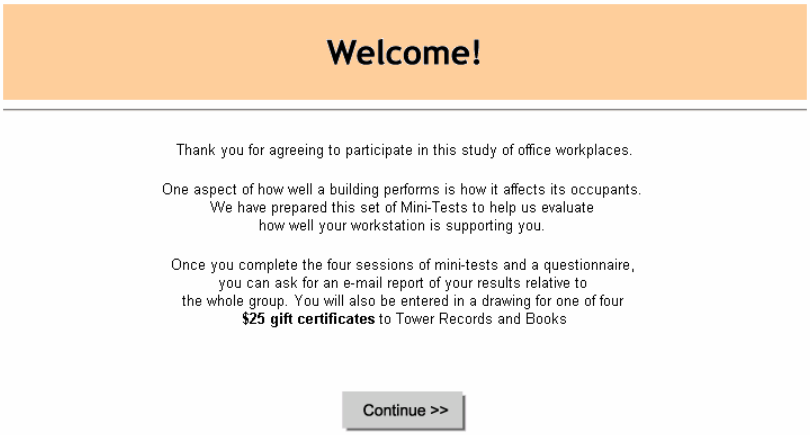
Thank you for participating in the Office Workstation Evaluation Questionnaire.

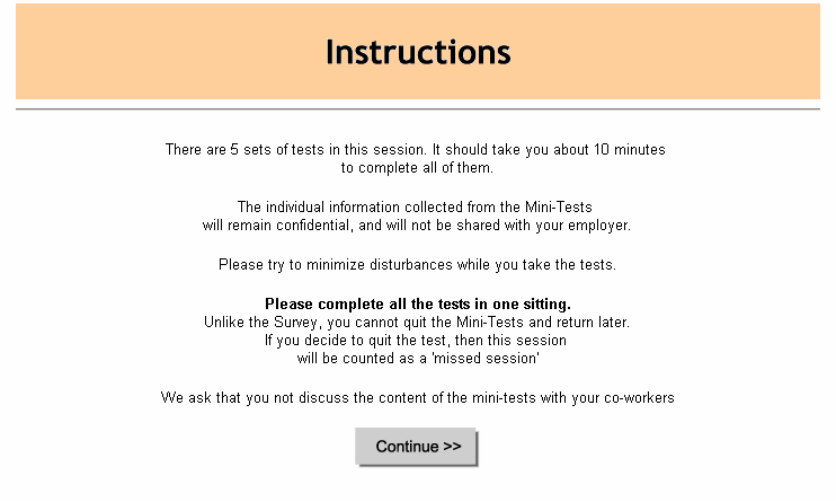
Any comments on the survey can be e-mailed to info@h-m-g.com

Review | End

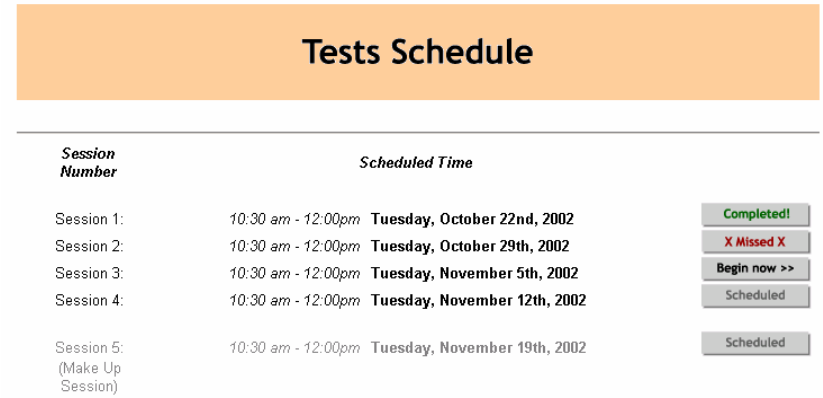
7. MINI-TESTS – SCREEN SHOTS

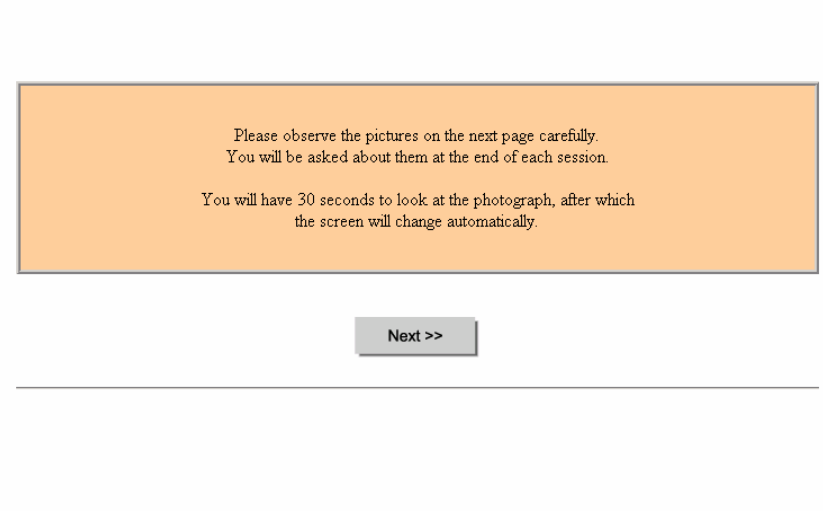
In this section, screen-shots of one session of the computer-based Mini-Tests administered to the participants is presented.




Instructions
There are 5 sets of tests in this session. It should take you about 10 minutes to complete all of them.
The individual information collected from the Mini-Tests will remain confidential, and will not be shared with your employer.
Please try to minimize disturbances while you take the tests.
Please complete all the tests in one sitting.
Unlike the Survey, you cannot quit the Mini-Tests and return later.
If you decide to quit the test, then this session will be counted as a 'missed session'
We ask that you not discuss the content of the mini-tests with your co-workers
Continue >>


LOG IN
Please enter your cubicle number below
This number should be posted somewhere on your cubicle partition
Continue >>

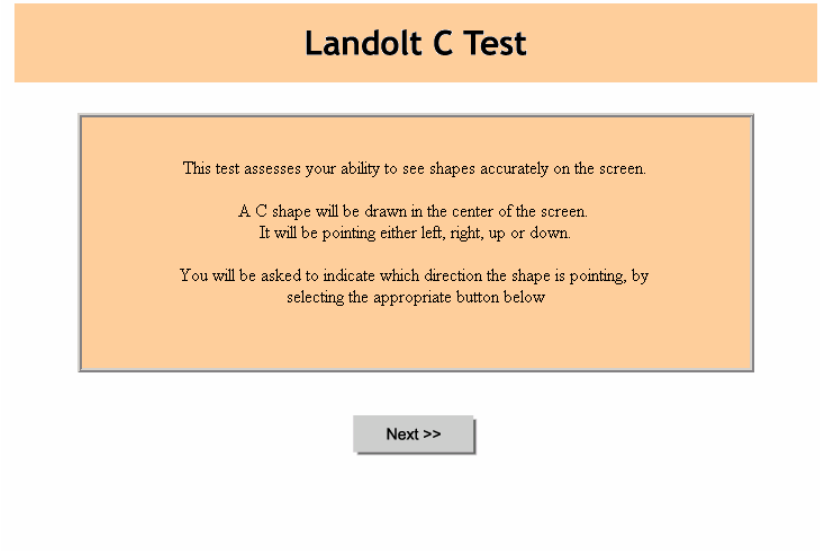

Tests Schedule
Session Number
Scheduled Time
Session 1: 10:30 am - 12:00pm Tuesday, October 22nd, 2002 Completed!
Session 2: 10:30 am - 12:00pm Tuesday, October 29th, 2002 X Missed X
Session 3: 10:30 am - 12:00pm Tuesday, November 5th, 2002 Begin now >>
Session 4: 10:30 am - 12:00pm Tuesday, November 12th, 2002 Scheduled
Session 5: (Make Up Session) 10:30 am - 12:00pm Tuesday, November 19th, 2002 Scheduled

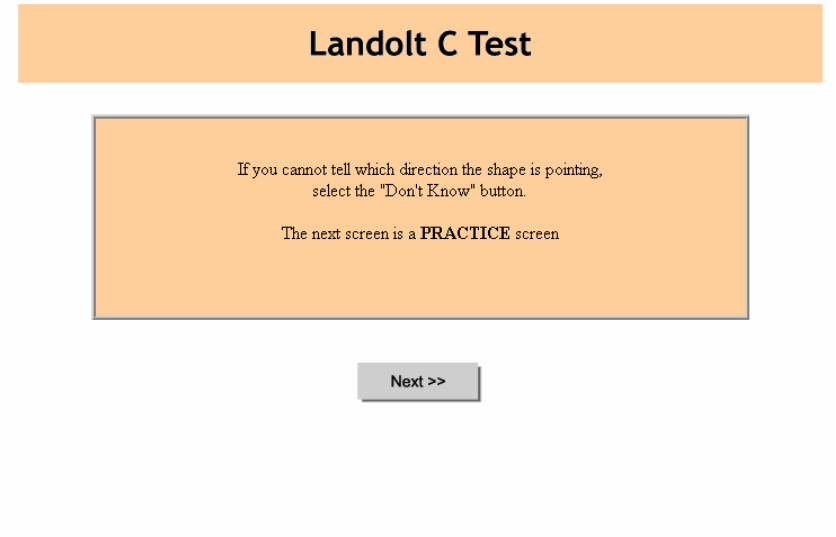

Please observe the pictures on the next page carefully.
You will be asked about them at the end of each session.
You will have 30 seconds to look at the photograph, after which the screen will change automatically.
Next >>

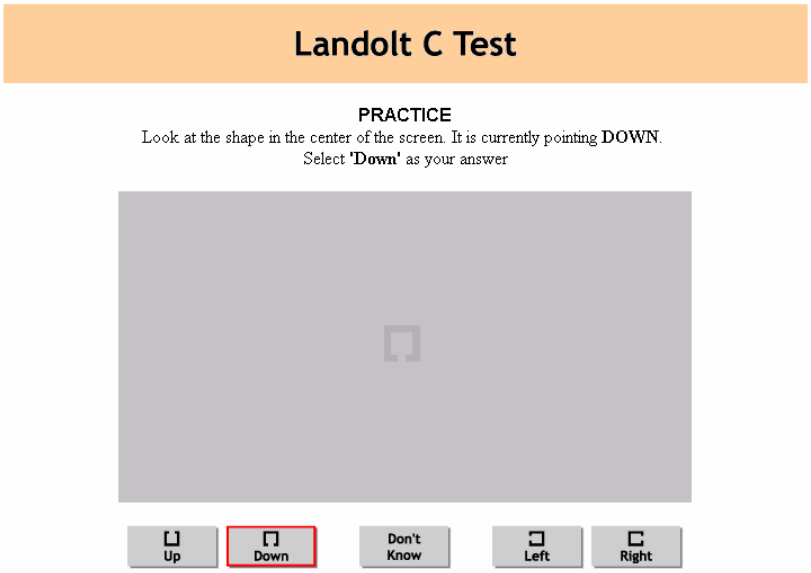
Thank you!

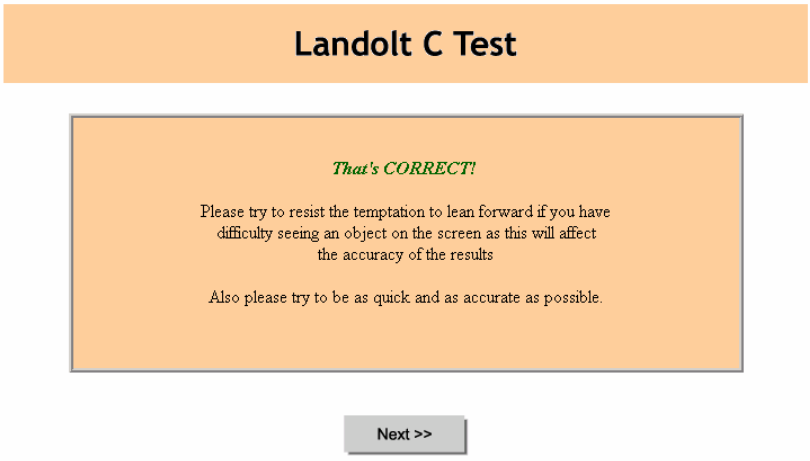
Please click below to continue ...

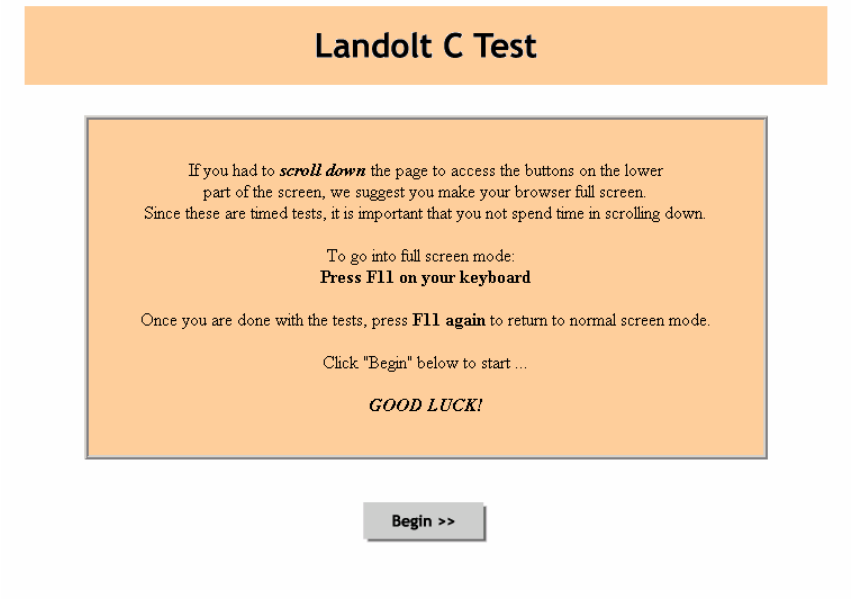
Continue >>

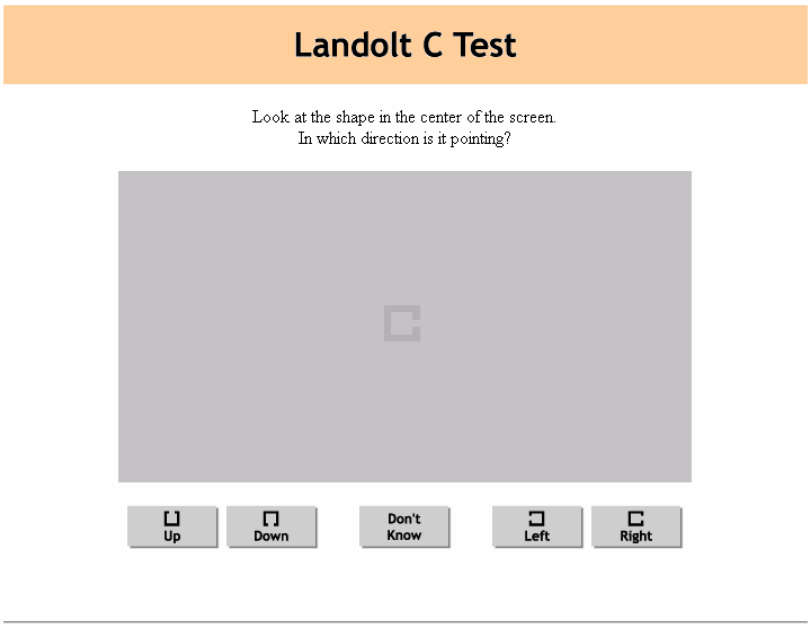

Landolt C Test
This test assesses your ability to see shapes accurately on the screen.
A C shape will be drawn in the center of the screen.
It will be pointing either left, right, up or down.
You will be asked to indicate which direction the shape is pointing, by selecting the appropriate button below
Next >>

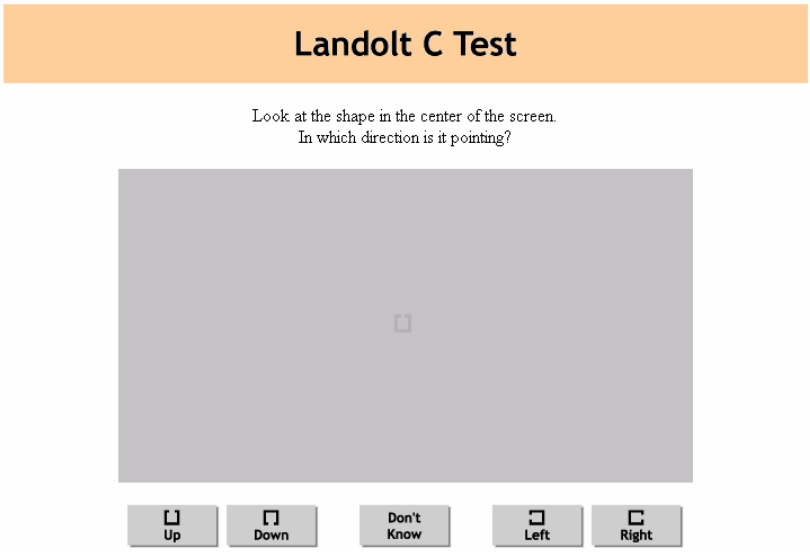

Landolt C Test
If you cannot tell which direction the shape is pointing, select the "Don't Know" button.
The next screen is a PRACTICE screen
Next >>

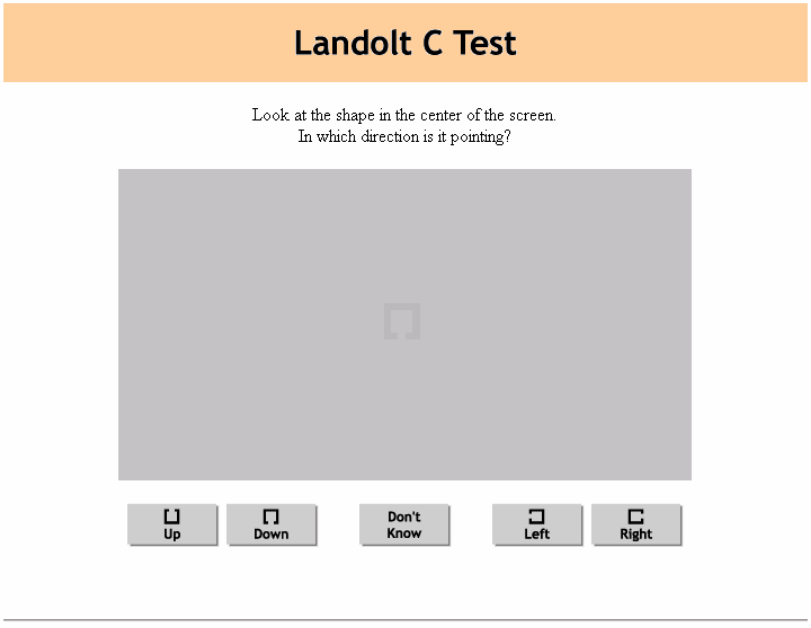

Landolt C Test
PRACTICE
Look at the shape in the center of the screen. It is currently pointing DOWN.
Select 'Down' as your answer
Up
Down
Don't Know
Left
Right

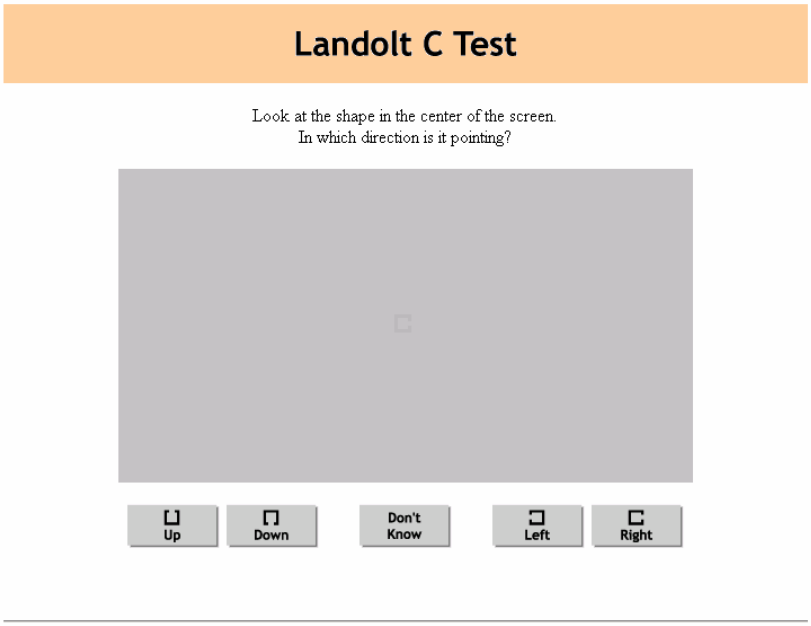

Landolt C Test
That's CORRECT!
Please try to resist the temptation to lean forward if you have difficulty seeing an object on the screen as this will affect the accuracy of the results
Also please try to be as quick and as accurate as possible.
Next >>

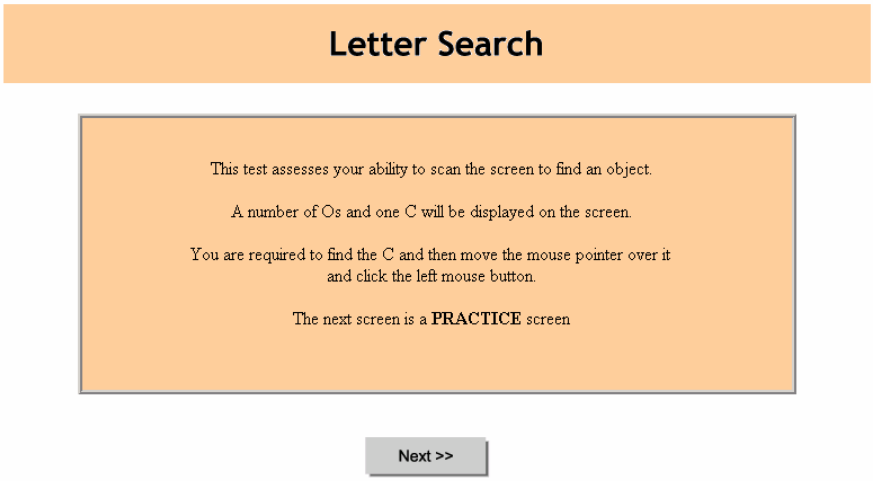

Landolt C Test
If you had to scroll down the page to access the buttons on the lower part of the screen, we suggest you make your browser full screen.
Since these are timed tests, it is important that you not spend time in scrolling down.
To go into full screen mode:
Press F11 on your keyboard
Once you are done with the tests, press F11 again to return to normal screen mode.
Click "Begin" below to start ...
GOOD LUCK!
Begin >>

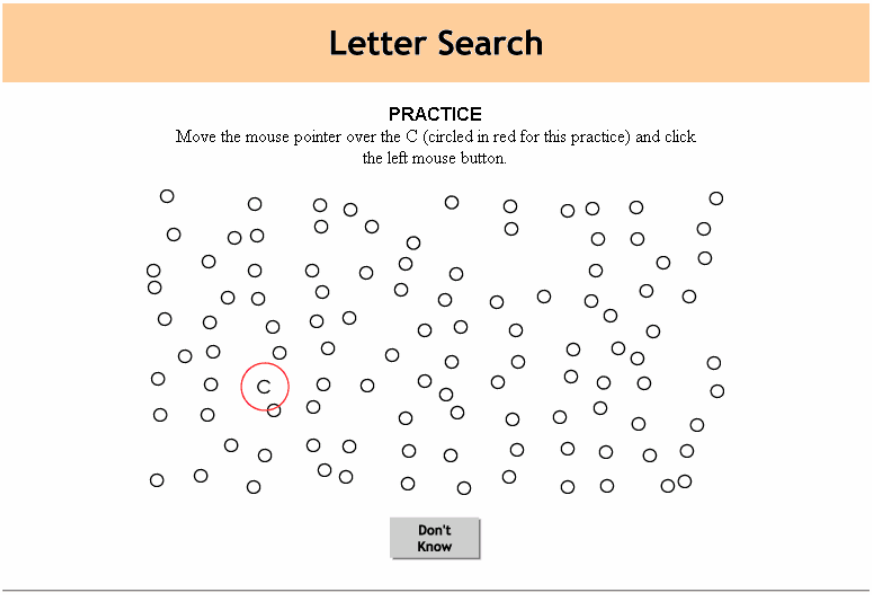

Landolt C Test
Look at the shape in the center of the screen.
In which direction is it pointing?
Up
Down
Don't Know
Left
Right

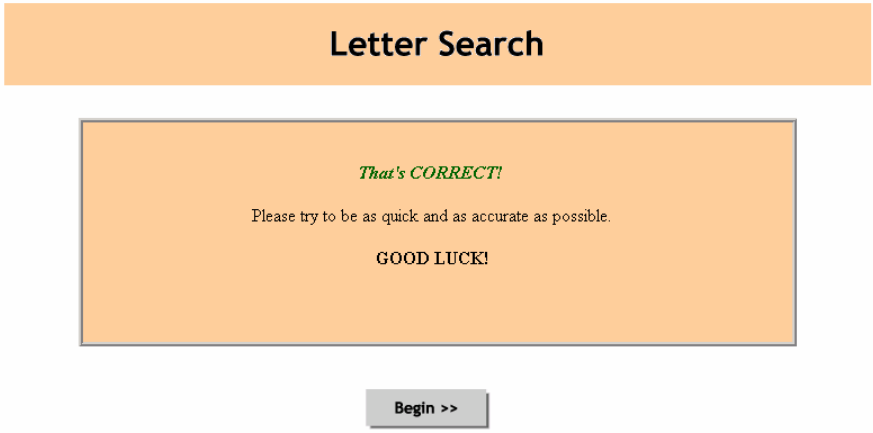

Landolt C Test
Look at the shape in the center of the screen.
In which direction is it pointing?
Up
Down
Don't Know
Left
Right

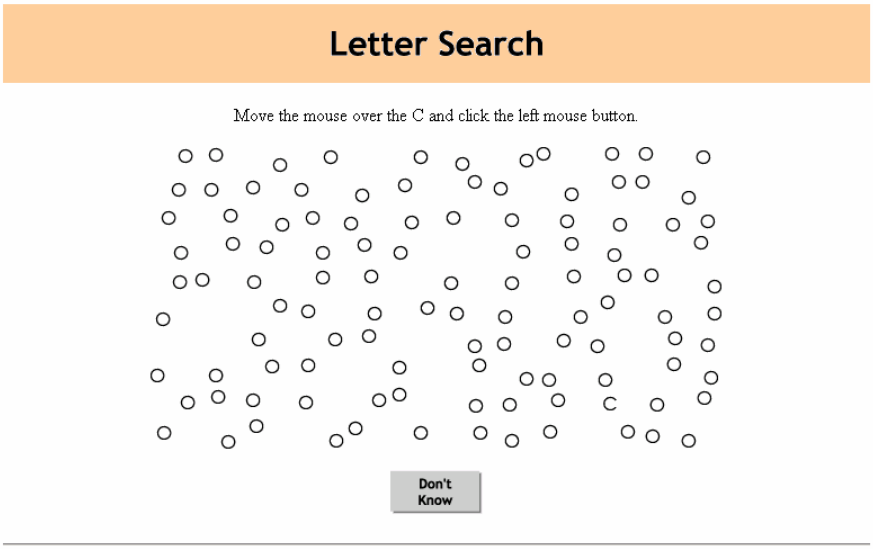

Landolt C Test
Look at the shape in the center of the screen.
In which direction is it pointing?
Up
Down
Don't Know
Left
Right

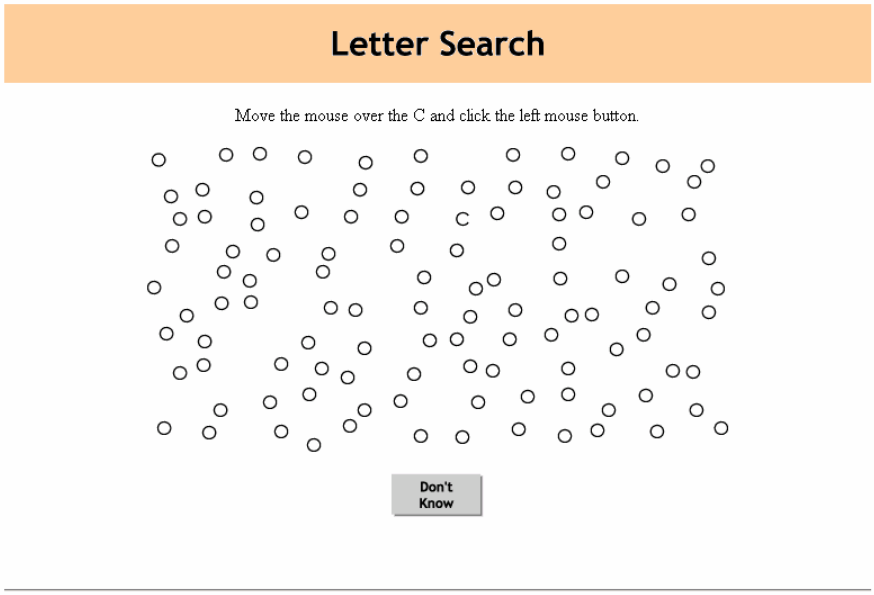

Landolt C Test
Look at the shape in the center of the screen.
In which direction is it pointing?
Up
Down
Don't Know
Left
Right

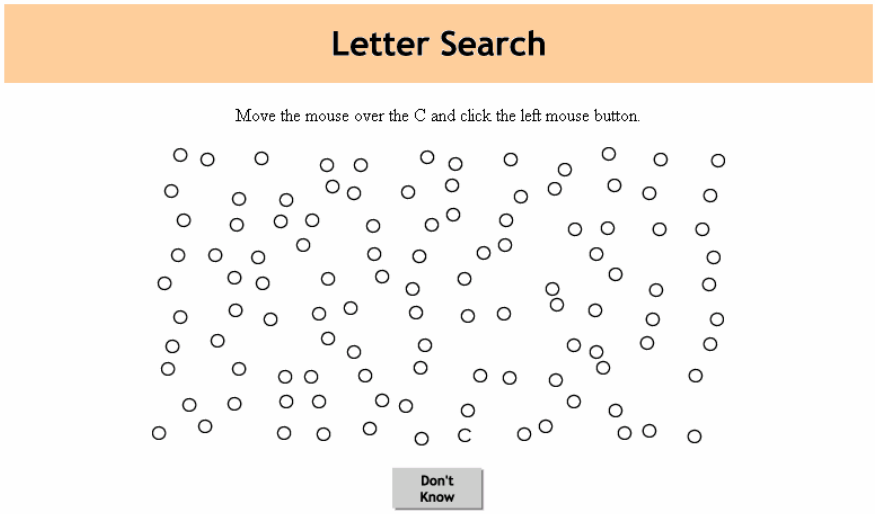

Letter Search
This test assesses your ability to scan the screen to find an object.
A number of Os and one C will be displayed on the screen.
You are required to find the C and then move the mouse pointer over it and click the left mouse button.
The next screen is a PRACTICE screen
Next >>

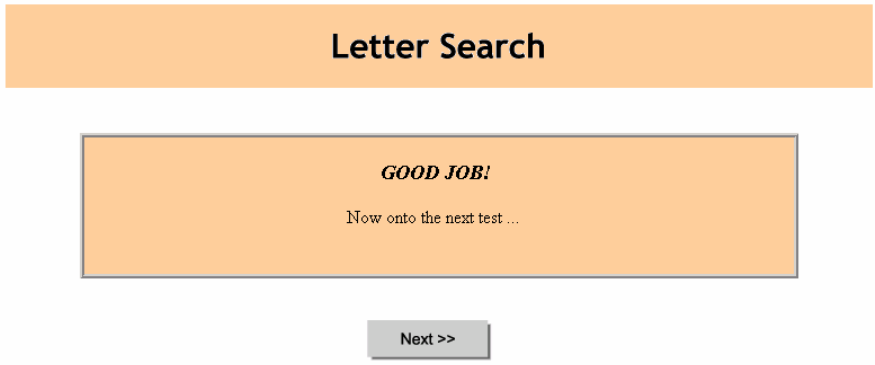

Letter Search
PRACTICE
Move the mouse pointer over the C (circled in red for this practice) and click the left mouse button.
C
Don't Know

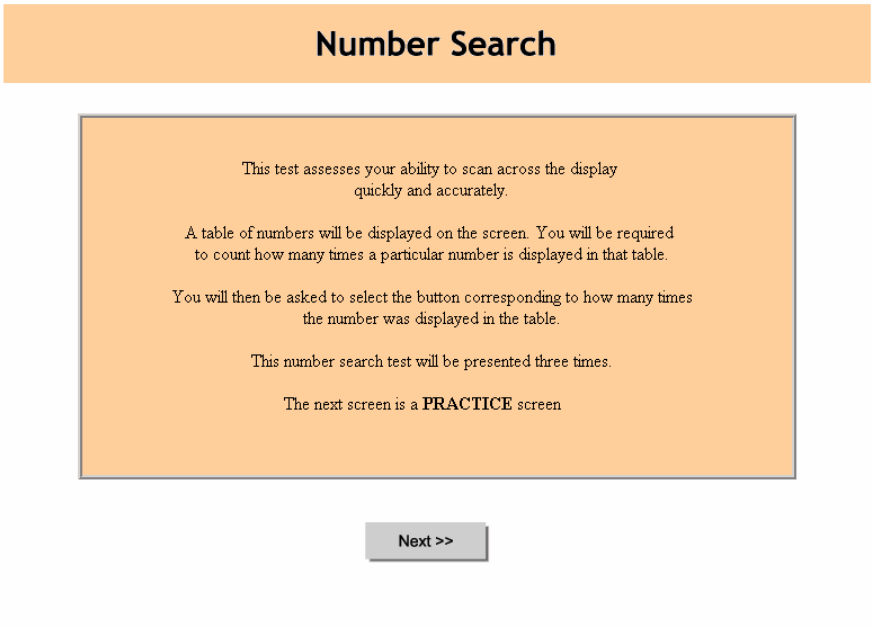

Letter Search
That's CORRECT!
Please try to be as quick and as accurate as possible.
GOOD LUCK!
Begin >>

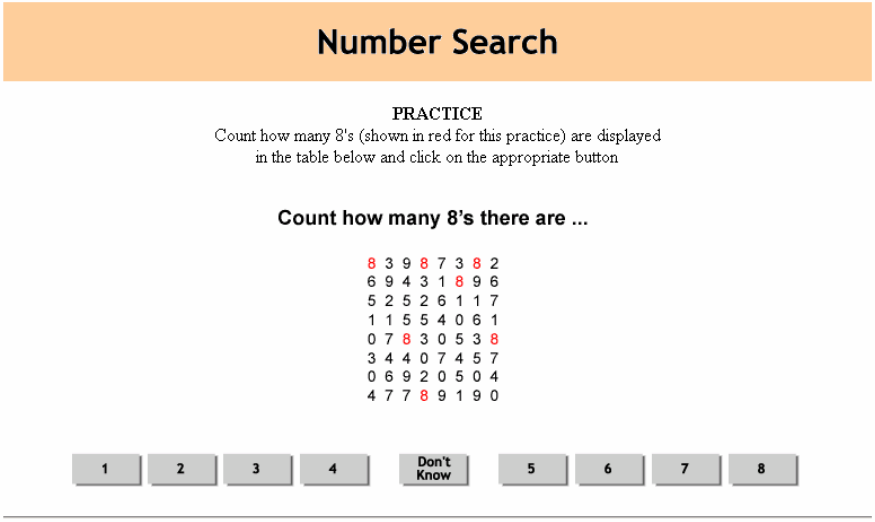

Letter Search
Move the mouse over the C and click the left mouse button.
C
Don't Know

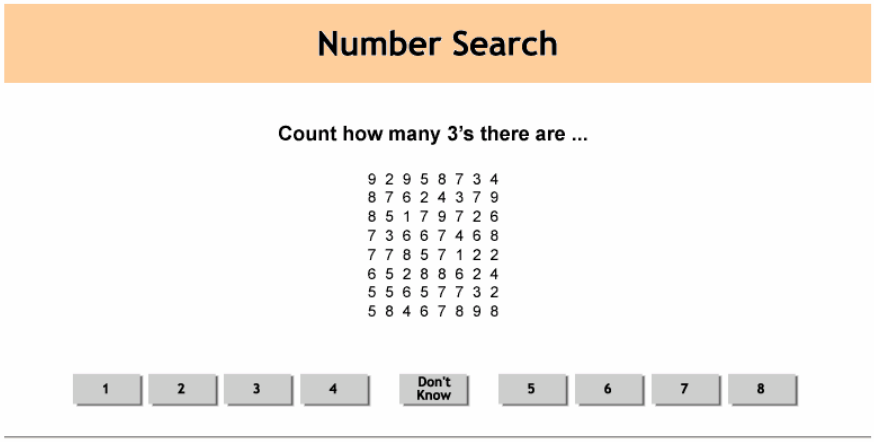

Letter Search
Move the mouse over the C and click the left mouse button.
C
Don't Know

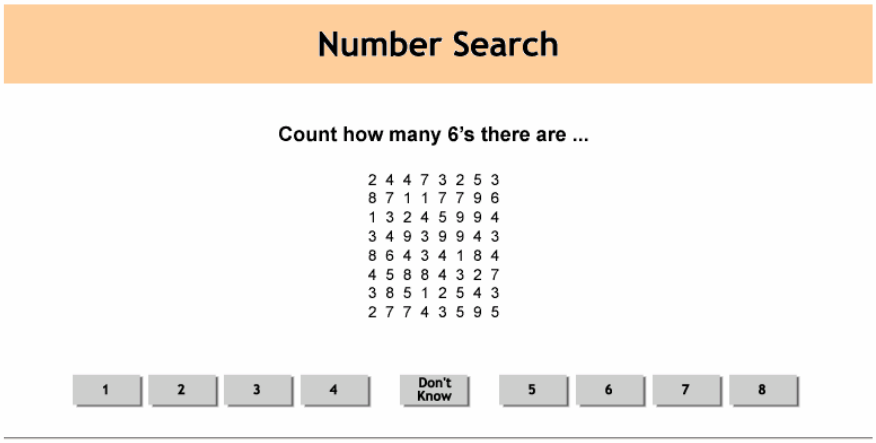

Letter Search
Move the mouse over the C and click the left mouse button.
C
Don't Know

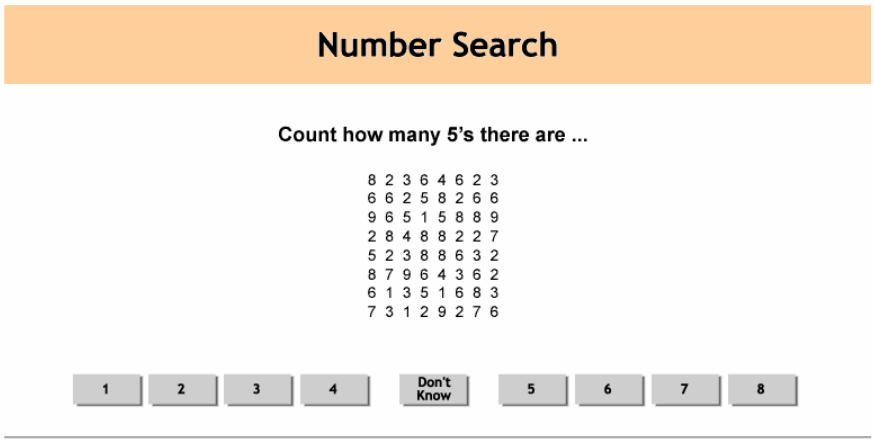

Letter Search
GOOD JOB!
Now onto the next test ...
Next >>


Number Search
This test assesses your ability to scan across the display quickly and accurately.
A table of numbers will be displayed on the screen. You will be required to count how many times a particular number is displayed in that table.
You will then be asked to select the button corresponding to how many times the number was displayed in the table.
This number search test will be presented three times.
The next screen is a PRACTICE screen
Next >>

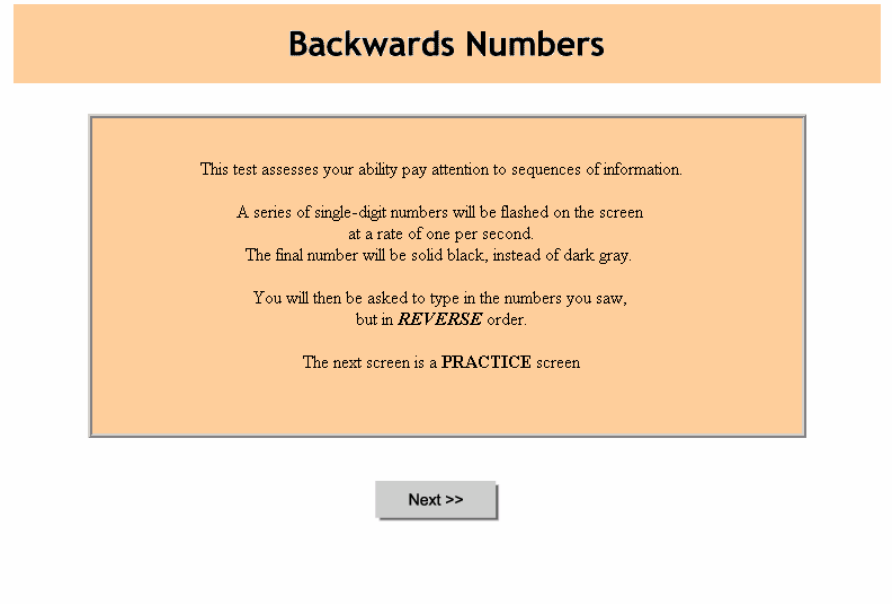

Number Search
PRACTICE
Count how many 8's (shown in red for this practice) are displayed in the table below and click on the appropriate button
Count how many 8's there are ...
8 3 9 8 7 3 8 2
6 9 4 3 1 8 9 6
5 2 5 2 6 1 1 7
1 1 5 5 4 0 6 1
0 7 8 3 0 5 3 8
3 4 4 0 7 4 5 7
0 6 9 2 0 5 0 4
4 7 7 8 9 1 9 0
1
2
3
4
Don't Know
5
6
7
8

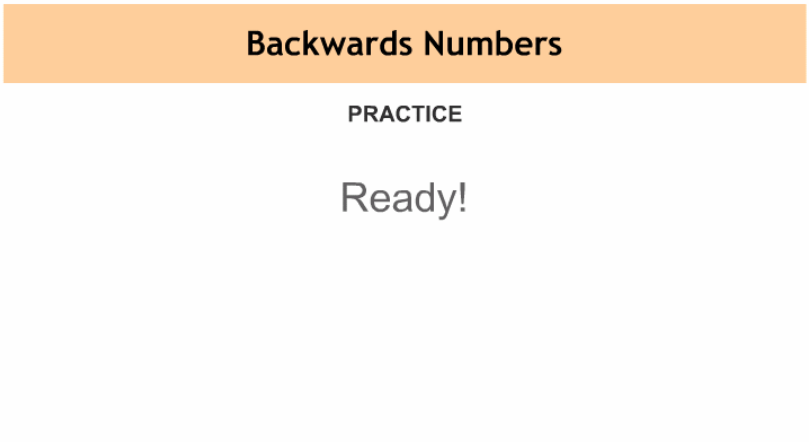

Number Search
Count how many 3's there are ...
9 2 9 5 8 7 3 4
8 7 6 2 4 3 7 9
8 5 1 7 9 7 2 6
7 3 6 6 7 4 6 8
7 7 8 5 7 1 2 2
6 5 2 8 8 6 2 4
5 5 6 5 7 7 3 2
5 8 4 6 7 8 9 8
1
2
3
4
Don't Know
5
6
7
8

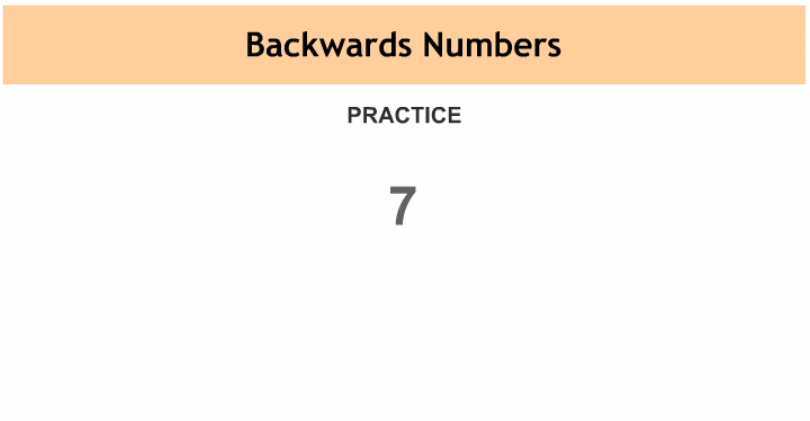

Number Search
Count how many 6's there are ...
2 4 4 7 3 2 5 3
8 7 1 1 7 7 9 6
1 3 2 4 5 9 9 4
3 4 9 3 9 9 4 3
8 6 4 3 4 1 8 4
4 5 8 8 4 3 2 7
3 8 5 1 2 5 4 3
2 7 7 4 3 5 9 5
1
2
3
4
Don't Know
5
6
7
8

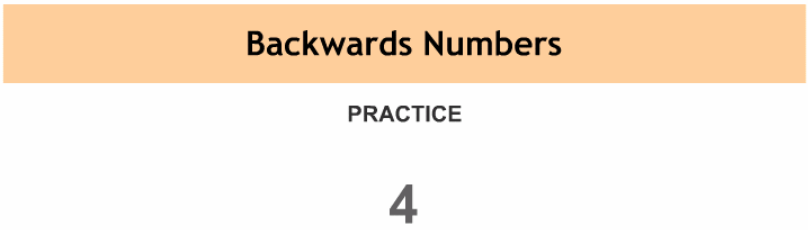

Number Search
Count how many 5's there are ...
8 2 3 6 4 6 2 3
6 6 2 5 8 2 6 6
9 6 5 1 5 8 8 9
2 8 4 8 8 2 2 7
5 2 3 8 8 6 3 2
8 7 9 6 4 3 6 2
6 1 3 5 1 6 8 3
7 3 1 2 9 2 7 6
1
2
3
4
Don't Know
5
6
7
8

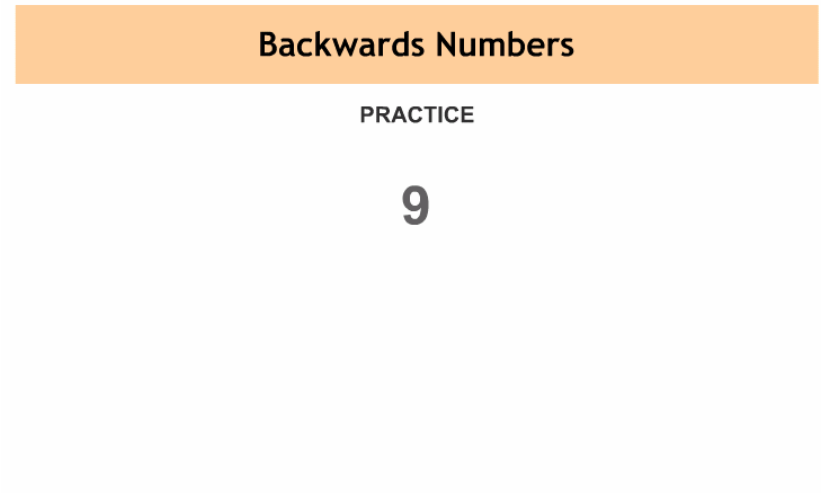

Number Search
WELL DONE!
Now onto the next test ...
Next >>

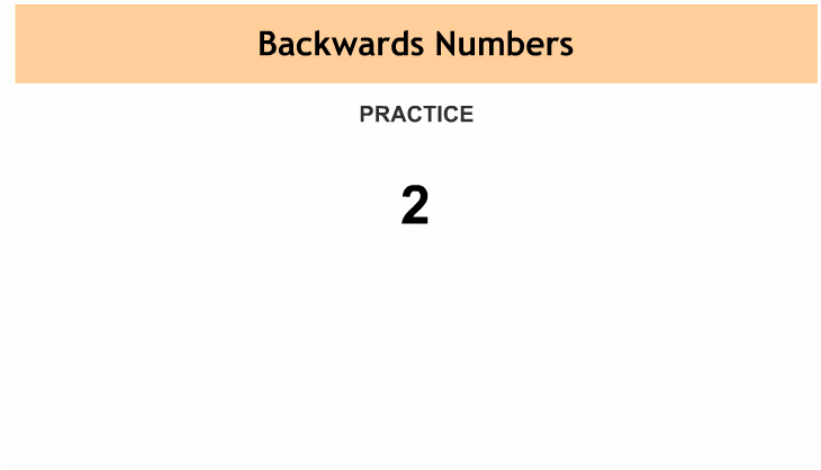

Backwards Numbers
This test assesses your ability pay attention to sequences of information.
A series of single-digit numbers will be flashed on the screen
at a rate of one per second.
The final number will be solid black, instead of dark gray.
You will then be asked to type in the numbers you saw,
but in REVERSE order.
The next screen is a PRACTICE screen
Next >>

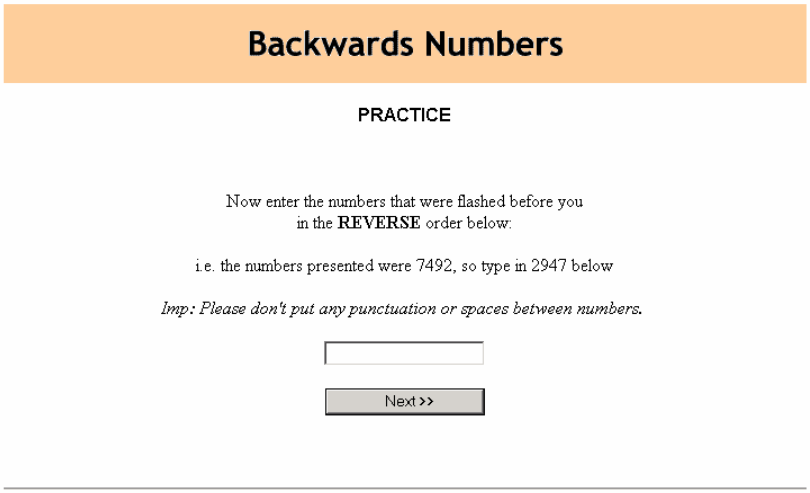

Backwards Numbers
PRACTICE
Ready!

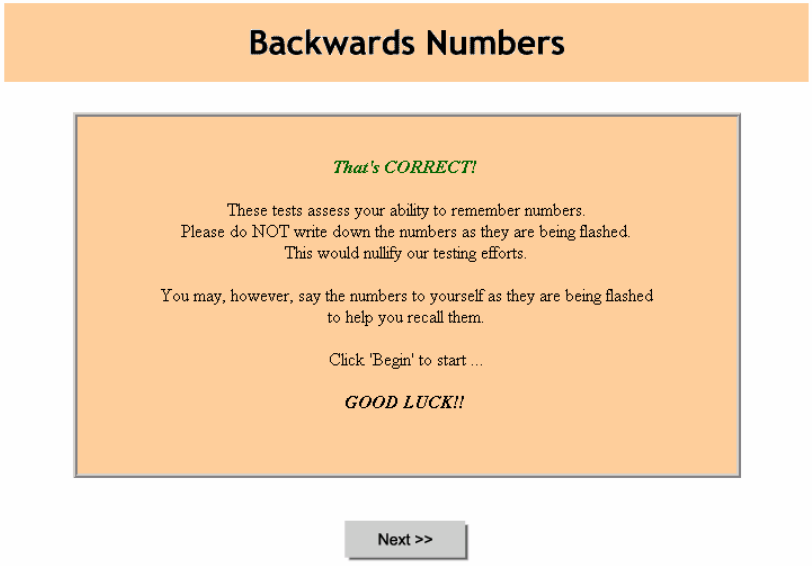

Backwards Numbers
PRACTICE
7

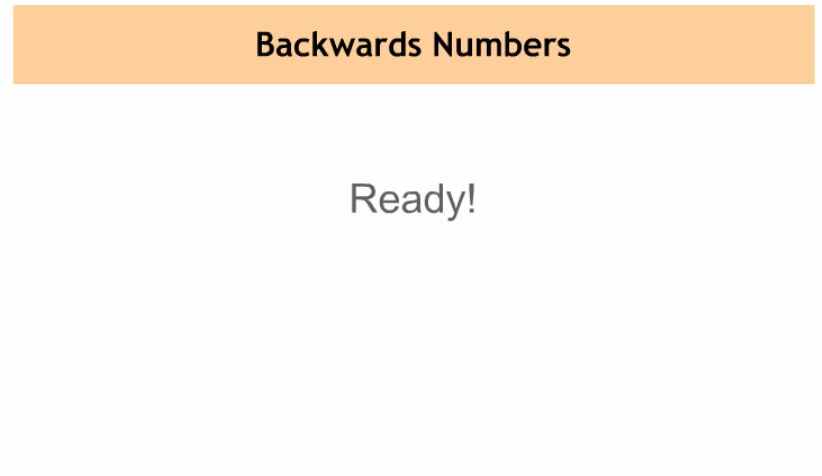

Backwards Numbers
PRACTICE
4

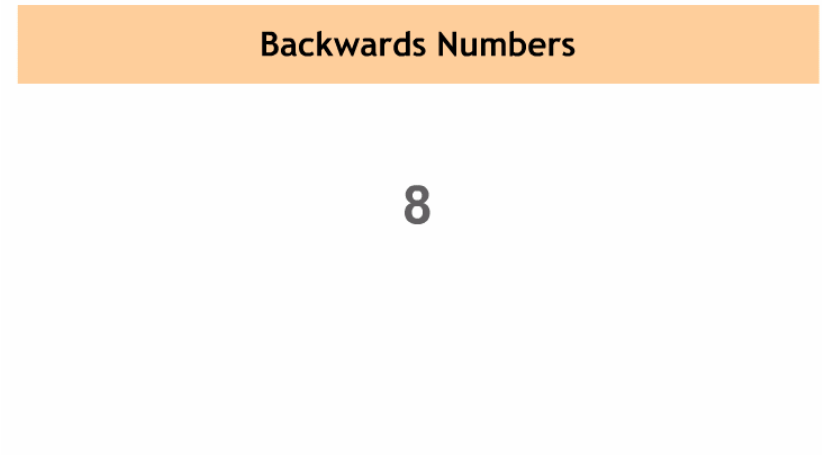

Backwards Numbers
PRACTICE
9


Backwards Numbers
PRACTICE
2


Backwards Numbers
PRACTICE
Now enter the numbers that were flashed before you
in the REVERSE order below:
i.e. the numbers presented were 7492, so type in 2947 below
Imp: Please don't put any punctuation or spaces between numbers.
Next >>


Backwards Numbers
That's CORRECT!
These tests assess your ability to remember numbers.
Please do NOT write down the numbers as they are being flashed.
This would nullify our testing efforts.
You may, however, say the numbers to yourself as they are being flashed
to help you recall them.
Click 'Begin' to start ...
GOOD LUCK!!
Next >>


Backwards Numbers
Ready!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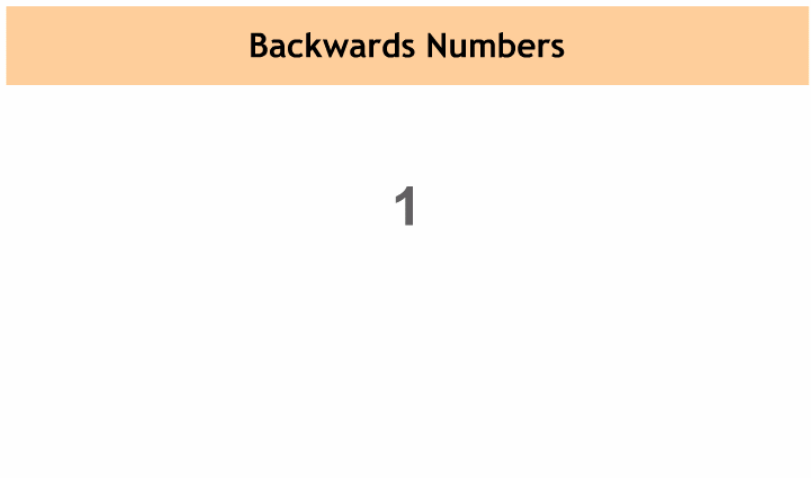
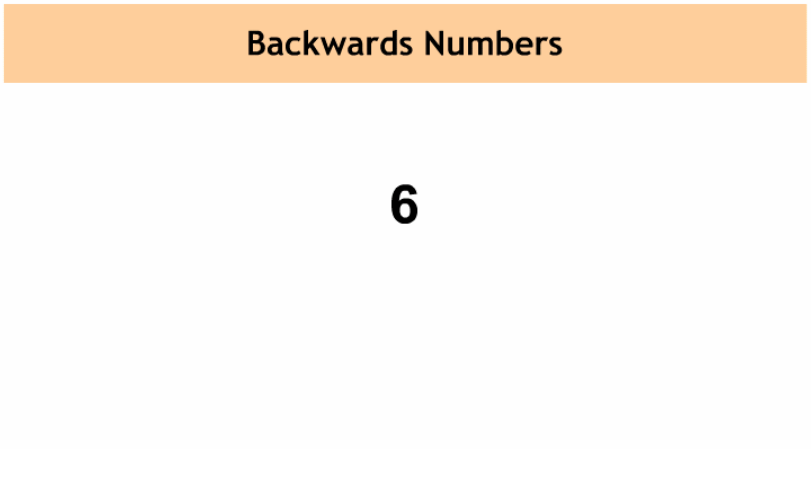
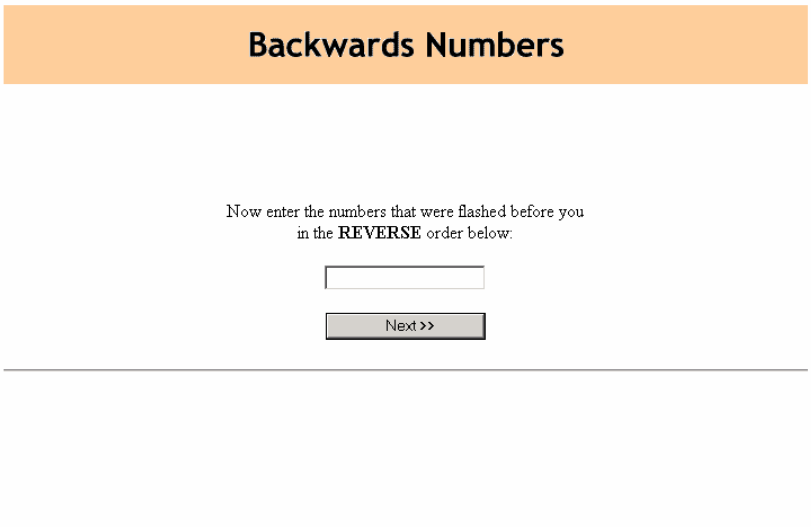
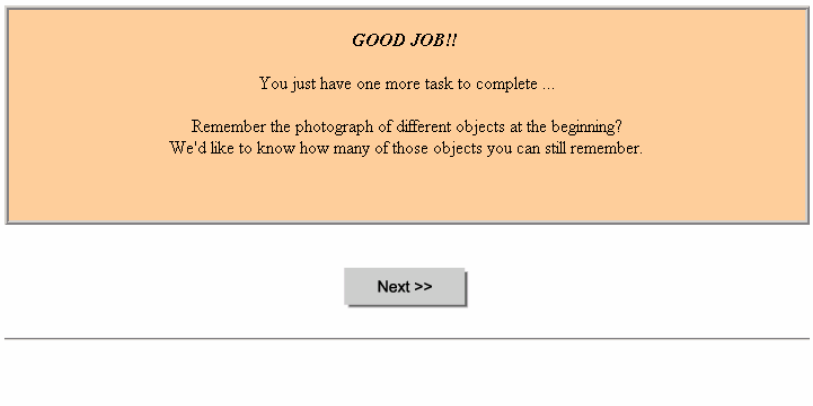
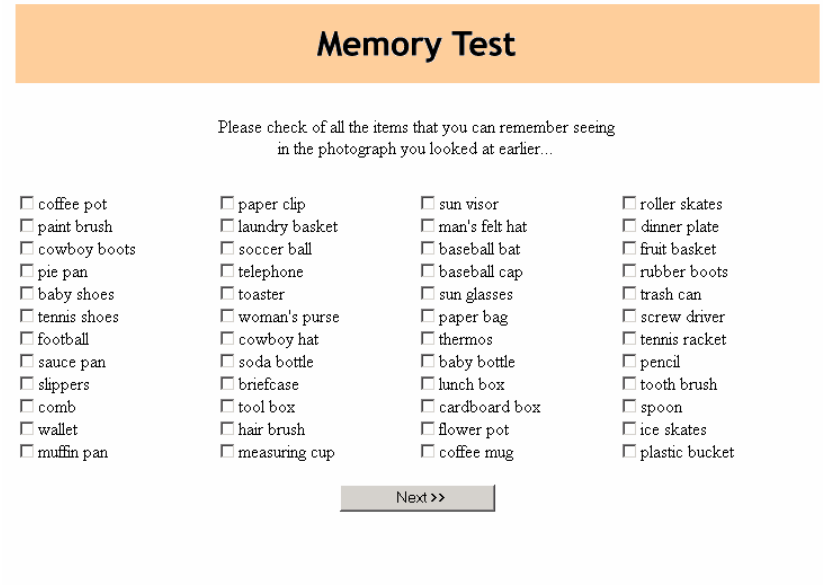

Backwards Numbers
1


Backwards Numbers
6



OTHER SCREENS OF BACKWARDS NUMBERS SKIPPED


GOOD JOB!!
You just have one more task to complete ...
Remember the photograph of different objects at the beginning?
We'd like to know how many of those objects you can still remember.
Next >>


Memory Test
Please check of all the items that you can remember seeing
in the photograph you looked at earlier...
coffee pot
paint brush
cowboy boots
pie pan
baby shoes
tennis shoes
football
sauce pan
slippers
comb
wallet
muffin pan
paper clip
laundry basket
soccer ball
telephone
toaster
woman's purse
cowboy hat
soda bottle
briefcase
tool box
hair brush
measuring cup
sun visor
man's felt hat
baseball bat
baseball cap
sun glasses
paper bag
thermos
baby bottle
lunch box
cardboard box
flower pot
coffee mug
roller skates
dinner plate
fruit basket
rubber boots
trash can
screw driver
tennis racket
pencil
tooth brush
spoon
ice skates
plastic bucket
Next >>

THANK YOU!

This session of your Mini-Tests is now complete!
We will ask you to take the next session on Thursday, November 7th, 2002

Please refrain from discussing these tests with your co-workers.

Thank you for participating in the Office Workstation Evaluation Mini-Tests.
The Heschong Mahone Group

Any comments on the survey can be e-mailed to info@h-m-g.com

8. CALIBRATION OF HOBO DATA LOGGERS

The environmental data was collected using five basic methods: 1.) Surveyor observations and measurements during a Saturday, when the Call Center was empty 2.) Automatic collection of data during the daily operation of Center via the use of miniature data loggers 3.) Daily observations of blind positions by a surveyor 4.) Information downloaded form the environmental management system (EMS) monitoring the HVAC system for the Center 5.) Other sources of information, such as weather data.

This section explains the methodology for calibration of data collected from the miniature data loggers.

The data loggers used were small matchbox sized Hobo data loggers type H08-004-02 from Onset Technologies to automatically collect illumination, temperature and relative humidity data through out the study period.

8.1 Merits and Limitations of HOBO Data Loggers

The Hobo data loggers (called Hobos from here on) have been widely used by researchers and scientists in the field of monitoring environmental data in buildings. As we used the loggers for study, many limitations in the loggers' illumination data collection were reveled, which to our best knowledge had not yet been reported by other researchers. In this section we discuss the anomalies we found in the data collected by the loggers and their possible explanations.

The Hobos provide data logging capability along with portability, ease of use and small size. Hobos were selected for our study, as we needed many data loggers with a capability to continually record data for the entire span of our study, also being minimally intrusive visually to the office workers in their workspaces.

8.1.1 Fluctuations in readings for lights with magnetic ballast

The Hobos provide a selectable sampling interval between 0.5 seconds to 9 hours, with total recording times up to 1 year. However, these readings are instantaneous in nature. Thus if the sampling interval is 15 minute, the reading for every 15 minutes is a snapshot taken instantaneously at that minute marker. Thus any sudden spikes in light levels coincidental to the sampling interval get reflected in the collected data.

We observed fluctuations in illumination readings of up to 20 to 40 fc for Hobos located near lights with magnetic ballasts (CFLs in the case of the Call Center). These fluctuations in readings were found at times when we expected a steady reading. The profile for a hobo seen in Figure 32 shows the "chatter" in what should typically be a smooth profile for lighting for four days.

On investigating the data from the various Hobos in different locations, we were able to determine that this chatter was the result of the Hobo being located below lights with magnetic ballasts. All hobos in the Headquarters building, with has magnetic ballast fixtures registered chatter. Also, Hobos placed below CFLs in the CSC building registered chatter. The phenomenon is possibly a result of the flicker from the magnetic ballasts operation which was captured by the instantaneous reading taken by the Hobos.

We were unable to confirm this with Onset Computer Corporation, the makers of Hobo data loggers and this inference is purely evidential.

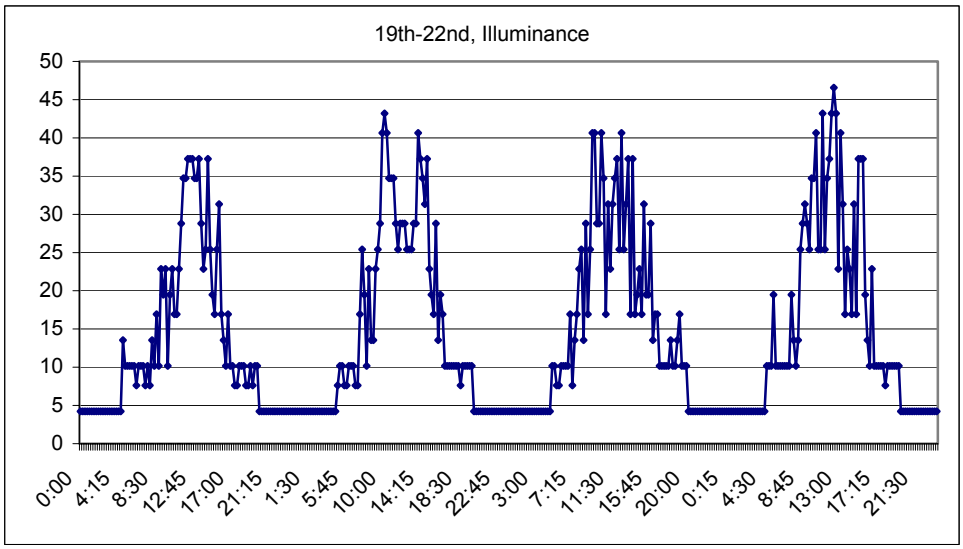


Figure 32: Illumination profile for a hobo under a CFL light showing chatter.

We also observed that the Hobo readings spike whenever there is a sudden change in data, and then normalize after a couple of readings. However, in our case since the sampling interval was 15 minutes, and the loggers were picking up the flicker, every second reading resulted into a data spike, causing much higher chatter in the data. This problem could have been partially solved by increasing the sampling rate, though that would have seriously affected the length of time available for collecting the data.

8.1.2 Limitation of angle of view for light meter

The Hobo's light sensor has angular response, which is a function of the vertical angle of the incident light. This angular response is shown in Figure 33. The graph shows that the light sensor is most responsive, and hence accurate for light falling directly perpendicular to it, i.e. at 0^{o}. As the angle of light changes on either direction from the perpendicular, the sensor's responsiveness to it decreases sharply. The sensor is unresponsive to light falling from beyond 40deg from the normal.

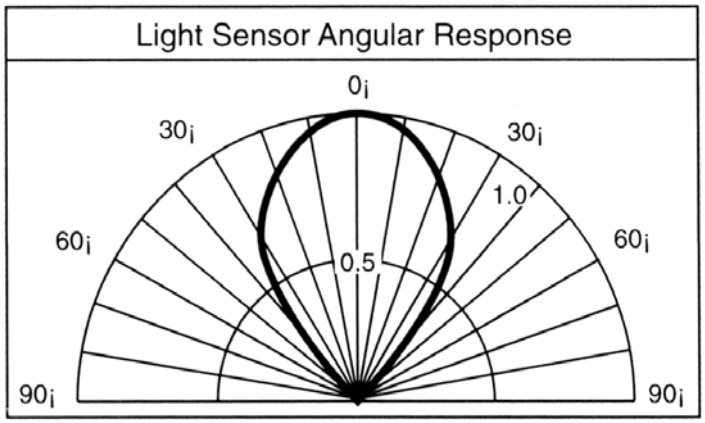


Figure 33: Light sensor generic angular response chart for Hobos.

Hence the Hobos could only record the light falling from above, mainly from the ceiling, skylights, or reflected window lights off the ceiling. The readings from Hobos were hence limited. To correct them, a hand-held Minolta T-1H light meter was used. The light meter has a range of 0 to 100,000 fc with a color-corrected and cosine-corrected sensor.

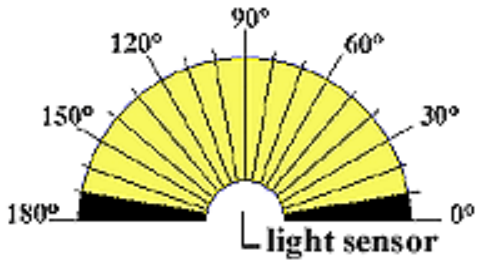


Figure 34: Diagram of illuminance sensor's field of vision for Minolta T-1H

Figure 34 gives the Minolta sensor’s field of vision. The sensor "sees" down to 80 degrees from the zenith. Darkened areas are beyond the sensitivity of the meter.

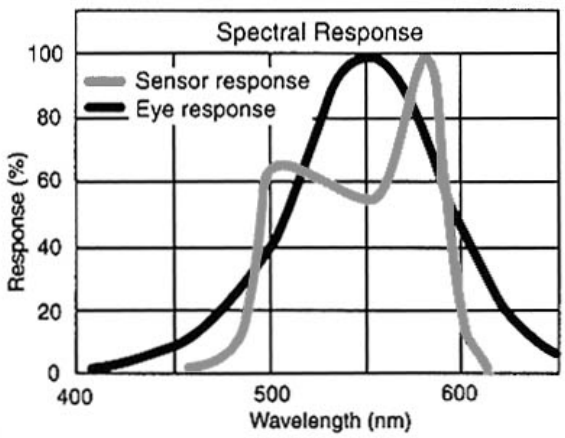


Figure 35: Spectral response of the Hobo sensor compared to the spectral response of the eye

Figure 35 shows the spectral sensitivity of the Hobo in comparison to the standard photopic sensitivity of the eye, which is also used as the spectral calibration curve for the Minolta handheld light meters used in the Saturday surveys. This graph shows that the Hobos have higher sensitivity in the green (500 nm) and green-yellow (575 nm) ranges and lower sensitivity in the blue to purple (less than 475 nm), and orange to red (600 nm+) sections of the spectrum. However, we do not have the spectral power density plots for the lamps used in the various buildings. Nor do we have readings for the spectral content of daylight, which varies throughout the day. Thus, we cannot complete the analysis to determine the difference in Hobo sensitivity to the electric light sources versus the daylight sources.

8.2 Calibrating Hobos to Ensure Uniformity in Readings

Onset Technologies report the Hobos to have a range of 2 to 600 footcandles and an accuracy of ±2 footcandles, ±20% of reading.

A preliminary study was done to determine the extent of variation in readings between the Hobos themselves. On doing a check of data recorded by the Hobos for the same light conditions (109 fc) amongst the 51 Hobos used in the study, we found that about 61% of Hobos show a variation in reading of about 10 to 30 fc, 18% showed a variation of (–10) to 05 fc and 21% showed a variation of 35 to 50 fc.

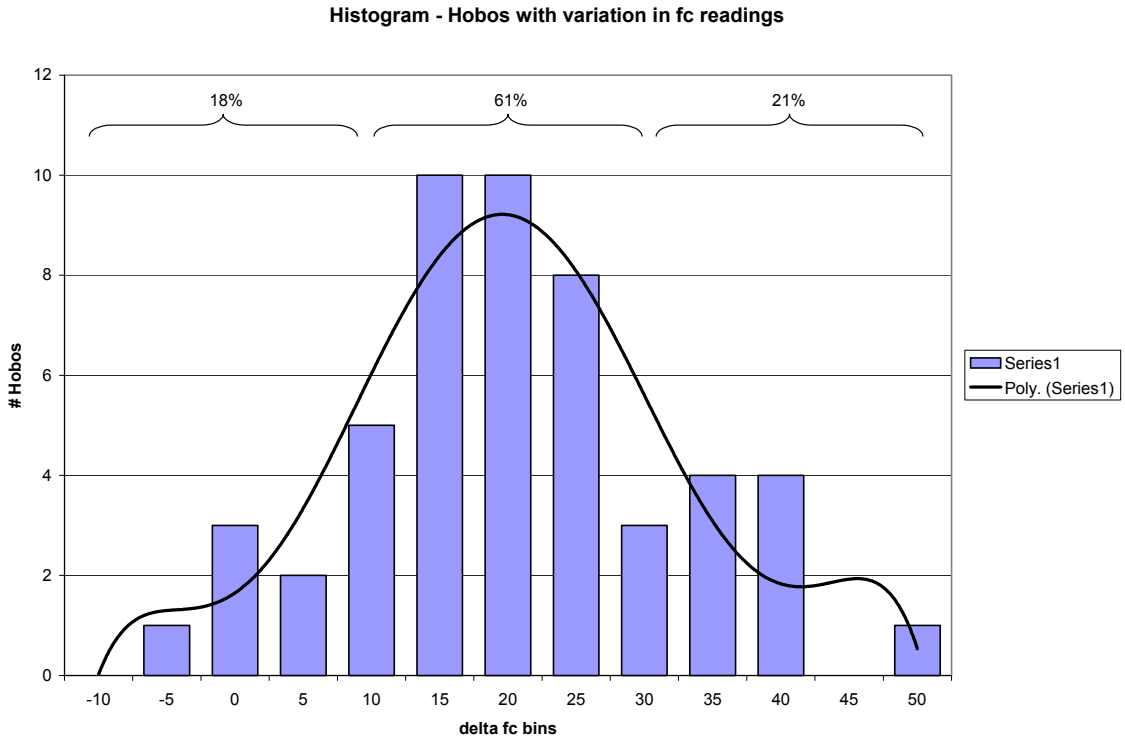


Figure 36: Histogram showing number of Hobos with variations in fc readings.

To ensure that the readings from all the Hobos used in the study were uniform and comparable, they had to be calibrated to a single source.

We used a Li-Cor Li-210sa photometric sensor attached to a Campbell model type: CR10 data logger to calibrate the Hobos. The Campbell data logger was placed in a control room with a single window and an electric light source. The Hobos were placed next to the Campbell light sensor so as to expose them to the same light conditions as the Campbell sensor. Daylight conditions in the room changed over the course of the day which was recorded by both the Campbell and the Hobos. Variation in electric light level was also provided by occasionally turning the electric light in the room on and off.

Data from the Hobos and the Campbell were downloaded and compared. A linear relation between the readings from the Hobos and the Campbell was computed by plotting a graph of the two readings. The linear equation was forced to a “0” Y intercept and the slope of the equation was taken as a multiplier to calibrate the Hobo readings.

The graph in Figure 37 is an example of the calibration of one of the Hobo. A similar analysis was made for each of the 51 Hobos and a slope of the equation was calculated for each. The Hobo readings were then corrected using this slope.

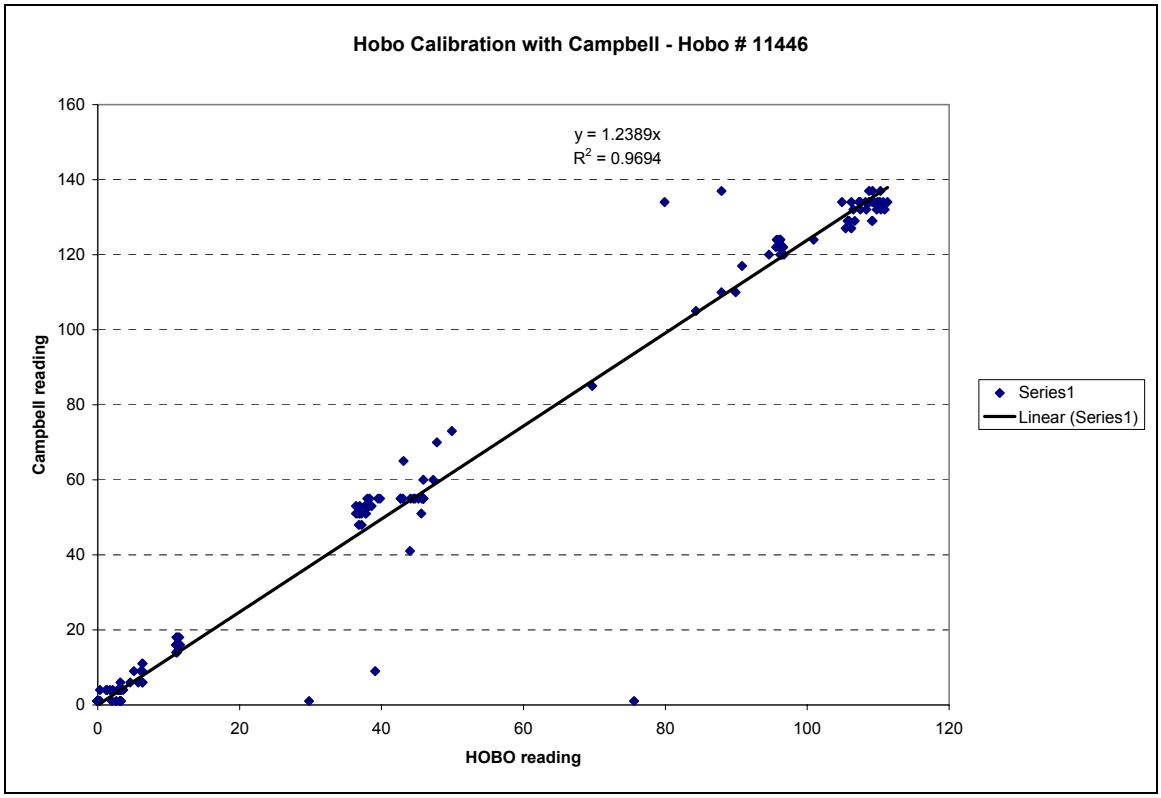


Figure 37: Example of a Hobo calibration with Campbell data

8.3 Call Center Study - Calibration procedure for Hobos and Calculation of Cubicle Illumination using Hand-Held Light Meter

As explained in Section 8.1, the illumination readings collected by the Hobos was restricted due to the narrow view angle on the light sensor in the Hobo. Only light incident on the sensor from directly above it and a few degrees from this normal angle was captured by the Hobo. This meant that light incident on the Hobo from sources like windows on the sides and electric lights not directly above or close to the Hobo, will not be captured accurately.

A hand-held Minolta light meter T-1H which had a wider view angle was used in addition to the Hobos, to collect instantaneous illumination readings at the cubicles positions to calibrate the readings from the Hobos (discussed later). The hand-held readings also provided an additional check on the Hobo readings.

8.3.1 Hand-Held light meter data collection

Since Hobos were placed in various locations all throughout the Call Center floor, each Hobo received a different amount of light from various directions unique to its position. For this purpose, readings with the Minolta hand-held light meter

(called hand-held from hereon) were taken at the same position where the Hobos were installed, by keeping them directly adjacent to the Hobo.

Along with the reading on the Hobo position, hand-held readings were also taken for each cubicle. These readings were taken at 4 feet height from the floor above the chair of the occupant in the cubicle. This position is closest to the position of the occupant head when he/she is seated on the chair, facing his/her desk and computer, and allowed the most consistent measurement between cubicle locations. These hand-held readings at the cubicles were then used to calibrate the hourly illumination readings from a nearby Hobo to that cubicle, as explained in later in this section.

The hand-held readings were taken for the four extremes of daytime light conditions that the Hobo can be exposed to. They are summarized below:

1. Lights off, blinds closed
2. Lights off, blinds open
3. Lights on, blinds closed
4. Lights on, blinds open

Daylight only condition can be calculated by subtracting either condition 1 reading from condition 2 reading or condition 3 from condition 4 reading. The electric light level reading can be calculated by subtracting condition 1 from condition 3 readings or condition 2 from condition 4 readings.

For the Call Center Phase 1 study, these readings were taken between 10:00am and 12:00pm on a Saturday when the building was unoccupied. For the Call Center Phase 2 study, these readings were taken at three times in the day between 10:00am and 12:00pm, 12:30pm and 2:30pm, and 3:00pm and 5:00pm on a Saturday.

To check if there is any dimming in electric lights, the calculation for electric light was done by both the methods mentioned above and compared. Hand-held readings were taken along the transects D, F, H and J in the Call Center. Some noticeable variation in readings (dimming of more than 5 fc) were seen 10 and 15 ft from the south window in transect D, 5 and 10 ft from the north window in transect F and 10 ft from the north window in transect J. Transect H showed no significant dimming. Some negative dimming (lights were brighter with windows open) was observed in transect D 25 ft from the north window and in transect J 10 ft from the north window. From these results we concluded that the dimming was not a constant feature in all the fixtures in the call center. There is anecdotal information collected in conversations with occupants and facility managers, at SMUD that the dimming of the lamps caused discomfort to the occupants, and hence on request of the occupant, the facility managers disabled or reduced the sensitivity of the some of the light meters on the dimmers. If this is true, then our findings, which show inconsistent dimming in the lamps, show dimming for only those fixtures that have not been disabled.

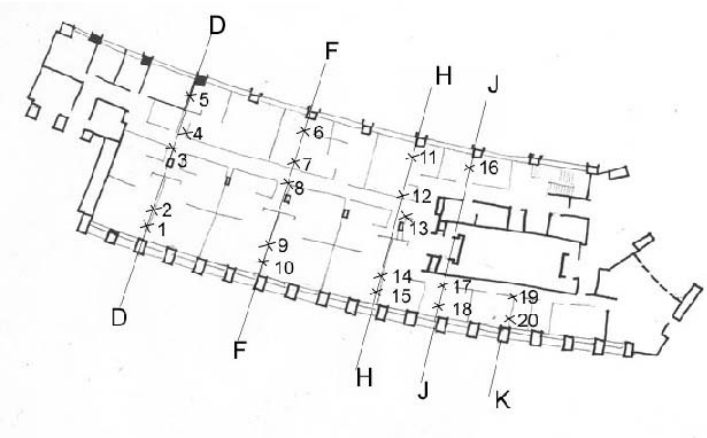


Figure 38: Call Center Plan showing location of transects.

Figure 39 and Figure 40 show profiles of the resulting electric and daylight illuminance data collected by the hand-held light meter through transects along the Call Center floor running south to north. Each row of cubicles is designated a position from the external wall, with S1 being the closest to the south wall, S1.5 and S2 moving further into the core. Rows of cubicles in the core are designated by C1 and C2 and the row of cubicles closest to north is designated N1, N1.5 etc.

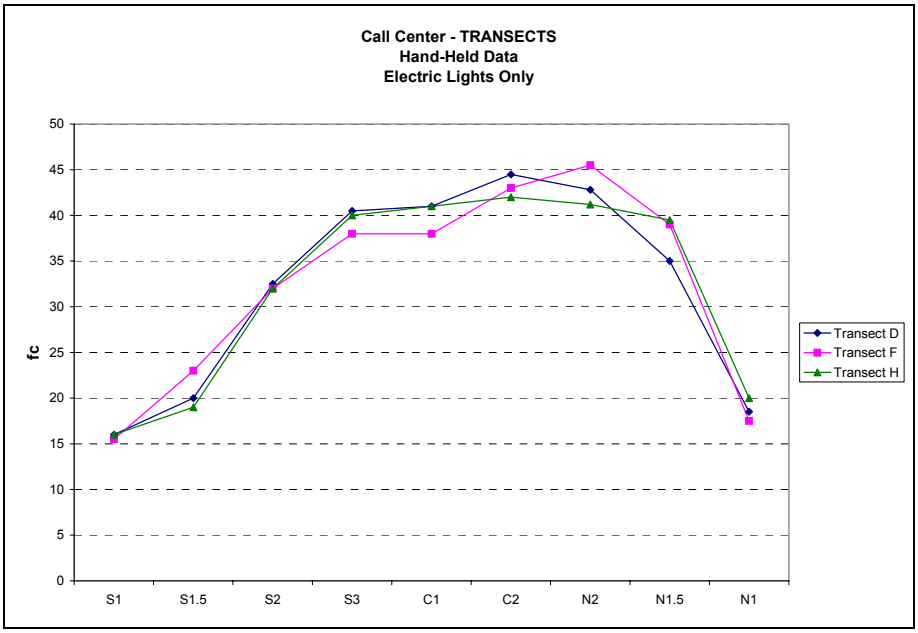


Figure 39: Electric Lights reading Transect D, F and H running S-N across the floor. Hand-held data collected over cubicles.

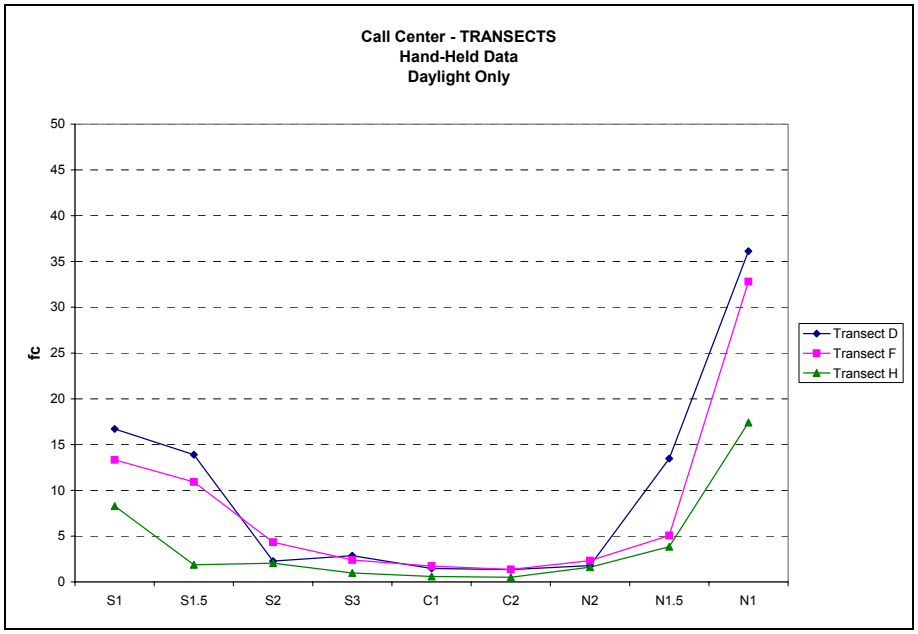


Figure 40: Daylight readings transects D, F and H running S-N across the floor. Hand-held data collected over cubicles.

8.3.2 Hobo calibration and calculation of hourly cubicle total illumination

To determine hourly illumination readings for each cubicle, the hourly readings of the Hobo ($Hobo_{calibrated}$) nearest to that cubicle was modified with respect to the hand-held readings taken at that cubicle and that Hobo using the following formula.

$$Cubicle_{hourly} = \frac{Cubicle_{\max}}{Hobo_{\max}} \times Hobo_{hourly} \qquad \text{-Eqn. 1}$$

$Cubicle_{hourly}$ = Hourly cubicle total illumination

$Cubicle_{max}$ = Hand-held reading taken at the cubicle above the occupants chair with blinds open and lights on (condition 4)

$Hobo_{max}$ = Maximum reading between 10:30am and 12:00pm for the day when the hand-held readings were taken.

$Hobo_{hourly}$ = Hourly data recorded by the Hobo

8.3.3 Calculation for Daylight Illuminance

To calculate daylight illuminance, it is assumed that the electric illuminance (EI) is a static reading for each cubicle. This electric illuminance was then subtracted from the hourly cubicle total illumination reading ($Cubicle_{hourly}$) calculated using Eqn. 1 described in Section 8.3.2.

Electric illuminance readings (EI), taken using the hand-held light meter were found to be erroneous (as described in Section 8.4.4). Hence a proxy for electric illuminance (TI_{min}) was used instead. Calculations for TI_{min} are described in Section 8.4.4.

Daylight Illuminance was calculated using Eqn. 2 below:

$$DI_{hourly} = Cubicle_{hourly} - TI_{\min} \quad \text{-Eqn. 2}$$

DI_{hourly} = Hourly cubicle daylight illumination

$Cubicle_{hourly}$ = Hourly cubicle total illumination

TI_{min} = Single occurrence of the lowest reading of illumination between 7:00am and 7:00pm, Mon - Fri for that cubicle

8.3.4 Calculation of Illumination Range

The single occurrence of the highest reading of daytime illuminance was computed (T_{max}) from the readings between 7:00 am and 7:00 pm, for the twelve days of interest. Using Eqn. 3 below, the maximum illumination range (RI) was calculated. This was also a static reading for every cubicle.

$$RI = TI_{\max} - TI_{\min} \quad \text{- Eqn. 3}$$

RI = Illumination range for that cubicle

TI_{max} = Single occurrence of the lowest reading of illumination between 7:00am and 7:00pm for that cubicle

TI_{min} = Single occurrence of the highest reading of illumination between 7:00am and 7:00pm for that cubicle

8.4 Call Center Study - Limitations in data collected on-site and work-arounds

The data collected on-site was constrained by many factors beyond our control such as limitations on access to the SMUD buildings, availability of personnel on weekends and after office hours to do onsite data collection, Hobo malfunction, EMS malfunction etc. As a result, some of the data collected onsite was not complete.

To work around these problems, we have at times made assumptions or used data collected on other days of the week or from other sources to compensate for missing data. In this section the problems in calibration of Hobo data due to missing onsite data, and our work-around is explained.

8.4.1 Missing hand-held data for maximum illuminance

For the purpose of calibration of Hobos, readings from the hand-held light meter were to be recorded for the four conditions described in Section 8.3.1. Due to factors beyond our control, we were unable to take readings for all four conditions.

On a Saturday, 11/23/2002 we recorded hand-held readings between 10:30am and 12:00pm for the following conditions of lighting in the Call Center space.

1. Lights off, blinds closed
2. Lights off, blinds open

On an earlier weekday we recorded hand-held readings for electric illuminance only, taking readings at night time between 6:30 pm and 8:30 pm for the following condition.

3. Lights on, blinds closed

From the recorded data for these three conditions, we calculated data for the fourth missing condition of – 'Light on, blinds open' ($HandHeld_{max}$) using the following formula.

Maximum Illuminance = Electric lights only + Daylight only

Condition 4 = Condition 3 + (Condition 2 – Condition 1)

8.4.2 Estimating corresponding Hobo data for Maximum Illuminance

Since the missing hand-held data for maximum illuminance was estimated (as described in Section 8.4.1), Hobo data corresponding to that light condition ($Hobo_{max}$) had to be estimated too.

We postulated that the maximum illumination condition (Blinds open, lights on) would occur sometime on one of the weekdays that week 11/16/2002 - 11/23/2002, between the hours of 10:30am to 12:00pm when the building was occupied. This assumption was based on our observations that lights are usually turned on by the workers in the mornings, and many of the occupants also open their blinds. Choosing the week of 11/16/2002 - 11/23/2002 also ensured that the sun angle for the incoming daylight was close to the sun angle on 11/23/2002 when the hand held readings for maximum illuminance were taken.

The $Hobo_{max}$ reading was taken to be the maximum instantaneous reading of that Hobo between 10:30am and 12:00pm for the days of the week of 11/16/2002 - 11/23/2002.

8.4.3 Hobo malfunction

The distribution of Hobos in the Call Center for Phase 2 was made based on expected variations in daylighting. We learned from Phase 1 that the most amount of variation in daylight was next to the windows. The variation decreased

rapidly towards the core, and the core showed almost no variation in lighting (about 3-5 fc). This is shown in the graph in Figure 41 from the Phase 1 study.

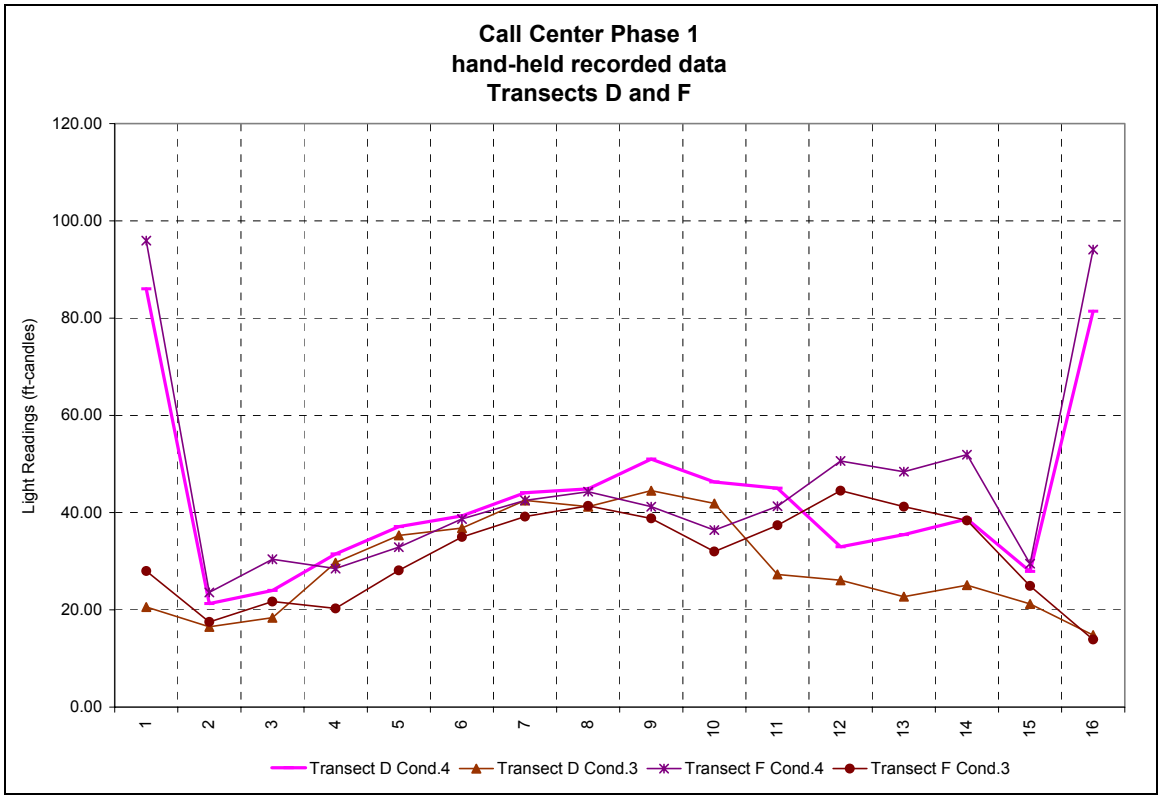


Figure 41: Transect through Call Center from Phase 1 study showing little or no variation in readings from Hobos in the core.

Hence in phase 2, 18 Hobos were placed near the north and south walls and 2 Hobos in the core. This arrangement gave us higher resolution of illuminance data for the cubicles close to the windows. On inspection of data for 6 of the days recorded by the Hobos, it was noticed that the two Hobos in the core showed large variations in lighting levels for the 6 days (about 15-18 fc). This is shown in the graph in Figure 42. This was counter to the data reported by Hobos placed in similar locations in Phase 1, which showed little or no variation at all (See Figure 41). Hand-held illumination data (shown in dotted line, labeled HH, in Figure 42) recorded by us was also not in agreement with the data being reported by the Hobos.

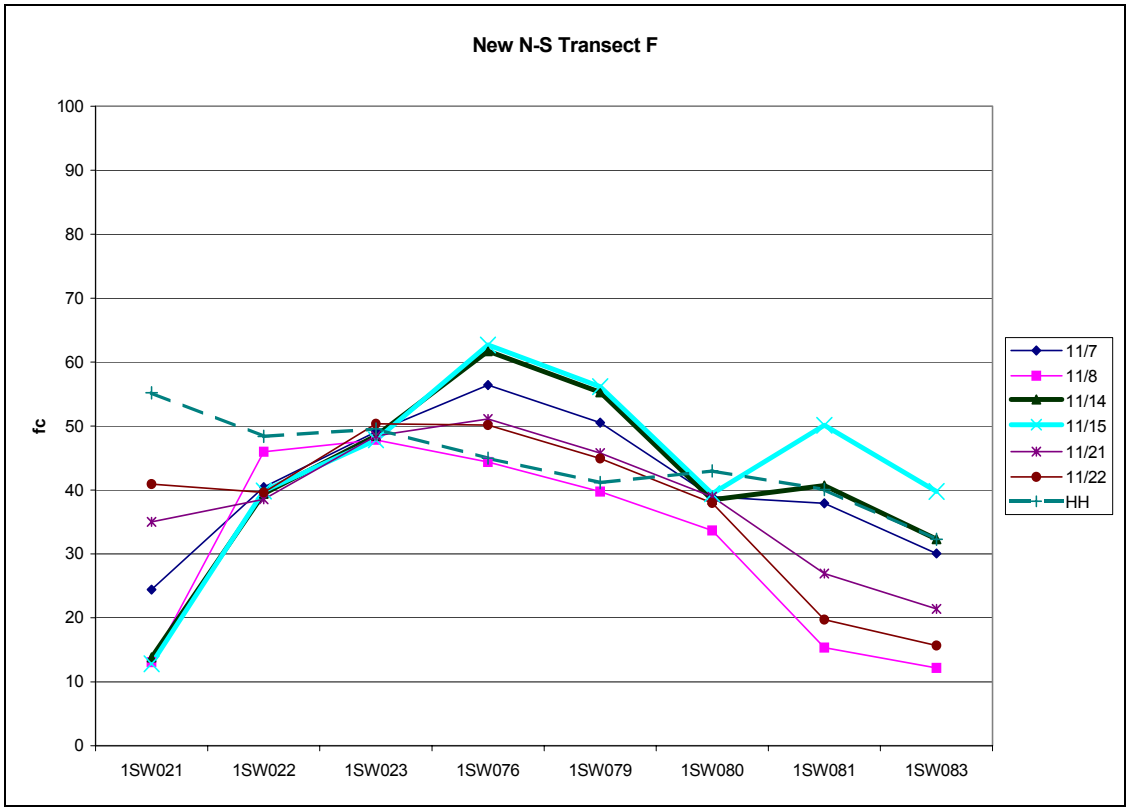


Figure 42: Transect F across the Call Center running N-S, showing light level readings at the cubicles recorded by Hobos.

On basis of these observations, we concluded that the two Hobos in the core were recording illumination data incorrectly due to malfunction. We decided to replace the hourly data of the Hobos with static illuminance data recorded by the Minolta hand-held light meter for their positions. Figure 43 shows the graph after the Hobo data was replaced with the static hand-held light meter data.

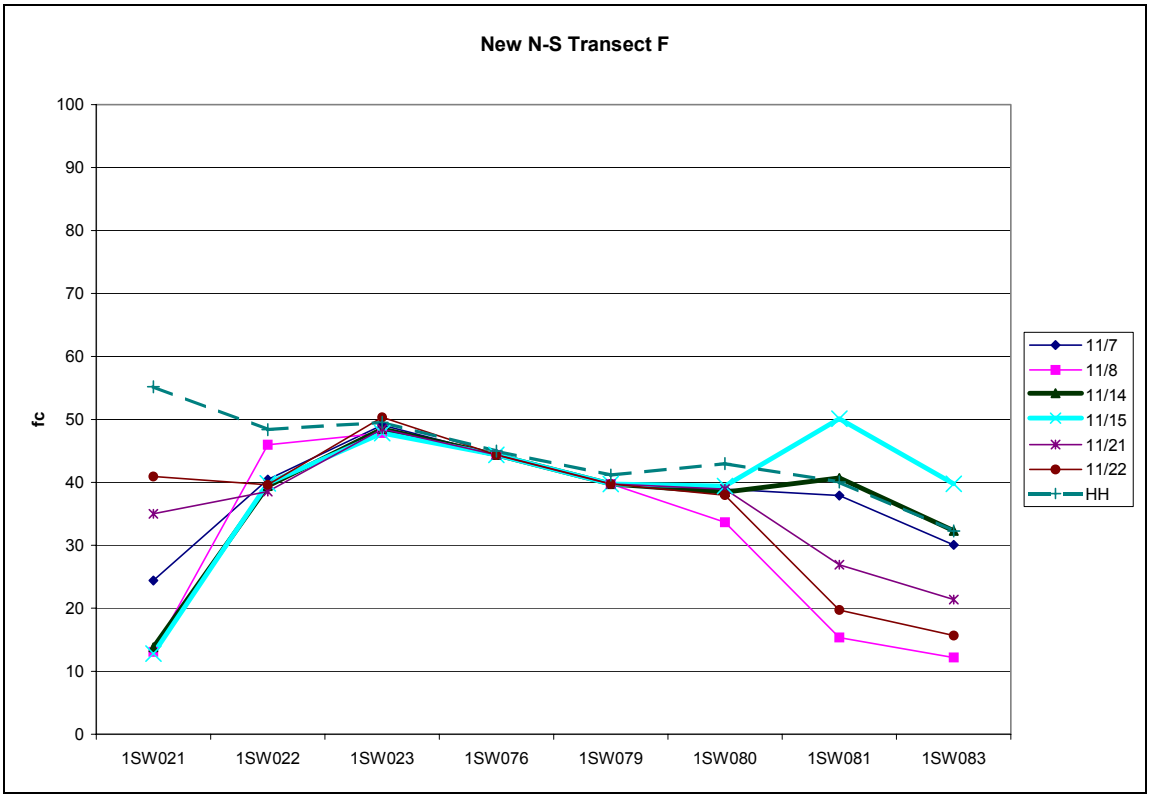


Figure 43: Transect F across the Call Center w/ Hobo data replaced running N-S, showing light level readings at the cubicles recorded by Hobos after core

8.4.4 Errors in recorded Electric Illuminance

To get only electric illuminance readings at the cubicles, it was decided to take readings using the hand-held light meter at night (after sunset), when the Call Center is unoccupied. All lights in the Call Center were turned on to record electric illuminance (EI).

On comparing these hand-held electric illuminance readings (EI) and total illuminance readings (TI) recorded by the Hobo, it was found that at many instances, total illuminance readings were less than electric illumination readings.

This discrepancy could be because of two possible reasons:

1. Extra lights were being turned on at night (not likely based on switching patterns and the variations in the lighting patterns we observed in the data)
2. The electric lights nearest to the windows were indeed dimming during the day, in spite of the fact that it was reported to us by the facilities management at SMUD that there was no dimming in this wing (likely given the pattern of the readings.)

To fix this problem, the single occurrence of the lowest reading of daytime illumination was taken as a proxy for electric illumination (TI_{min}). This reading was taken from the all readings between 7:00 am and 7:00pm, for the twelve days of interest. The TI_{min} reading was created for every cubicle and was a static reading. Figure 44 is a graph of a transect across the Call Center running N-S. It shows the daytime electric illuminance calculated from the hand held readings (EI – bold dark line) along with the calculated proxy for the electric illuminance (TI_{min} – dotted line). The other lines are total illuminance readings at various times of the day, recorded by the Hobo for each cubicle listed on the x-axis.

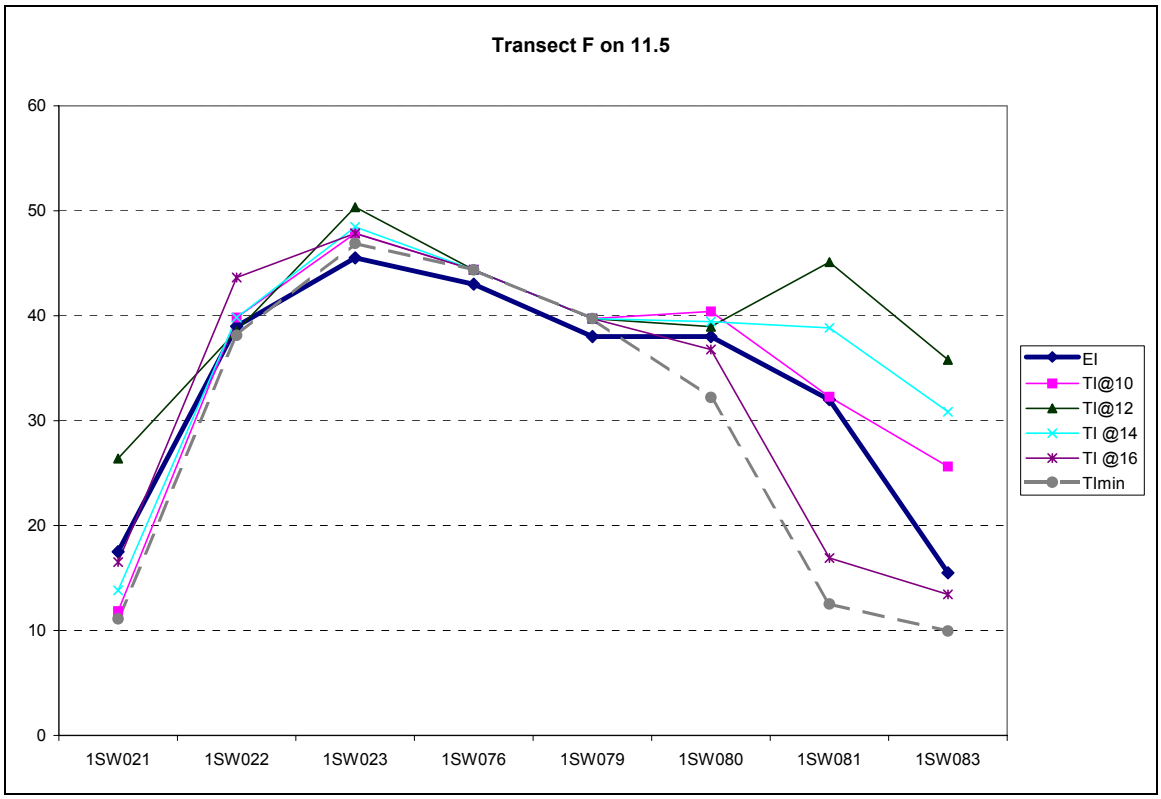


Figure 44: Transect F across the Call Center showing EI, TI@hour and TImin

8.5 Desktop Study - Calculation for Electric Illuminance

Similar to the Call Center study, we had two potential sources of information about electric illumination levels: the hand held readings taken on Saturdays under four blinds/lights conditions and the 15 minute interval Hobo readings collected during the study period. Unfortunately, the hand held data collected on Saturdays was not completed due to time restrictions and hence could not be used for all cubicles.

Our observation of Hobo data plotted as a graph for a typical day as shown in Figure 45, reveled that unlike in the Call Center study, the electric illumination could be easily identified from the graph as the flat line or 'shoulder' reading on

the graph before sunrise and after sunset. In Figure 45, the sunrise and sun set time are marked by the gray area. We could not use EImin as the minimum reading from 7:00 am to 7:00 pm for the entire set of data as we did in the Call Center study, since the different floors and buildings had different times for shutting off their electric lights.

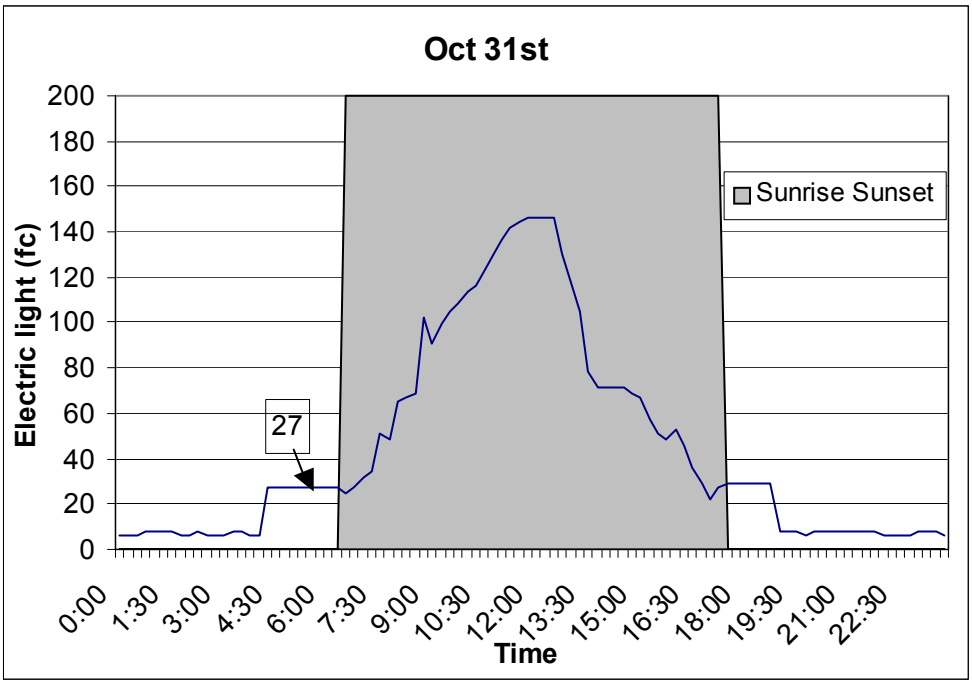


Figure 45: Plot of total illumination from a Hobo for 31st October. Grey area indicates time of day with sun

In the case shown in Figure 45, the electric illuminance reading was taken as 27 fc. These shoulder readings were considered for all cubicles in which the electric illuminance could not be determined due to missing or incomplete hand held electric illuminance data.

8.6 Desktop Study - Calculation for Daylight Illuminance

Daylight Illuminance was calculated using Eqn. 4 below:

$$DI_{hourly} = Cubicle_{hourly} - EI \qquad \text{-Eqn. 4}$$

DI_{hourly} = Hourly cubicle daylight illumination

$Cubicle_{hourly}$ = Hourly cubicle total illumination from Hobo readings

EI = Electric Illuminance from either hand held readings, or from shoulder readings from graphs of Hobo readings.

9. CALCULATION OF VENTILATION RATES

An important consideration for worker performance is the ventilation in their work environment. Ventilation rates in an office environment have been shown in past studies to affect the worker performance (Fisk study). We collected environmental data for calculating ventilation rates for both the Call Center and the Desktop study, but to insufficient data, calculated ventilation rates for only the Call Center study. This section describe in detail, the methodology used in processing and calculating the ventilation data based on the collected supply air, return air, outside air and mixed air temperatures.

9.1 Reason for Using CFM per Person as Ventilation Variable

The CFM Metric could be calculated as either CFM of outside air per square foot of area, or CFM of outside air per person which could be calculated by dividing the population of the Call Center for that hour with the outside air CFM. We choose CFM of outside air per square foot in order to avoid co-linearity with another important explanatory variable, *Population*.

Calculation of the outside air in cubic feet per minute (CFM) is described in sections below. The Call Center floor is served by two interdependent air handling units, AH14 and AH16, that serve 37% and 67% of the floor area respectively. Hence the final outside air CFM for the Call Center was calculated using the above fractions from both air handlers.

9.1.1 Calculation of O/A CFM per Person

To calculate Outside-Air CFM per Person ($CFM_{O/A}$) , first the outside air fraction which the economizer admits into the HVAC system, has to be calculated. A method was devised using air temperature readings at various points in the system to calculate outside air fraction. This is represented in the equation below:

$$O/A = \frac{\left(T_{mixed} - T_{return}\right)}{\left(T_{O/A} - T_{return}\right)} \qquad \text{- Eqn. 4}$$

O/A = Outside air fraction

T_{mixed} = Temperature of air mixed with the outside air at the air handler

T_{return} = Temperature returning from the conditioned space

$T_{O/A}$ = Outside air temperature

To calculate O/A CFM per Person from outside air fraction, the following equation was used:

$$CFM_{O/A} = \frac{O/A \times CFM}{N_{people}} \quad \text{- Eqn. 5}$$

$CFM_{O/A}$ = Hourly average of Outside-Air CFM per person

O/A = Outside air fraction

CFM = Hourly average of conditioned air delivered into the space, in cubic feet per minute

N_{people} = Number of people in the Call Center at the given hour

9.2 Missing Data in Calculation of Hourly Outside-Air CFM per Person.

During our study, some data that could not be measured or recorded by our survey team was requested from SMUD's Energy Management System. We requested SMUD for outside air temperature ($T_{O/A}$) recorded at a weather station located on the SMUD building site, return air temperature from the conditioned space in the Call Center (T_{return}), and amount of conditioned air being delivered into the Call Center (CFM). We requested this data for the entire period of our study. Unfortunately, the data set provided to us had two sections of missing data. These two sections were:

11/06/2002 10:51 am – 11/10/2002 11:51 am

11/20/2002 11:30 am – 11/22/2002 05:32 pm

This data was required for the calculation of the average hourly outside-air CFM per person. To be able to complete this calculation for the entire study period, we had to substitute missing data from other sources.

For days with missing $T_{O/A}$, T_{return}, and CFM, their corresponding data was substituted from other sources or calculated using available values. The missing $T_{O/A}$ data was substituted by using recorded hourly air temperature at the Sacramento airport for the missing days. This data was obtained from AccuWeather.com. The data was first checked for consistency with SMUD's weather data for the days other than those with missing data. This is explained further in Section 9.2.1.

The missing data for T_{return} was substituted by the average air temperature of the Call Center space recorded hourly by the Hobos.

The missing data for CFM was calculated by regression using outside-air temperature as a predictor for CFM. This is explained further in Section 9.2.2

9.2.1 Matching AccuWeather data with SMUD weather station data

To make sure that the data collected from the weather station at the airport, matched with the data collected at the SMUD weather station, provided by SMUD, we checked the AccuWeather outside air temperature data against SMUD's outside air temperature data for the days other than those with missing data. A plot of the data showed that the air temperature recorded in the AccuWeather weather file had

a. A time lag of about 90 minutes as compared to the SMUD weather file.

b. The daily temperature extremes (peaks and lows) for each day in the AccuWeather data were greater than the corresponding temperatures extremes in the SMUD weather file

This was probably due to the difference in location of about 15 miles between the two weather stations. The weather file from AccuWeather was hence shifted by 90 minutes to get better coherence between the two data sets.

9.2.2 Calculating missing CFM from outside-air temp

To calculate missing data for CFM, a hypothesis was made that, since the HVAC system is a variable air volume system, the CFM of conditioned air being delivered into the Call Center space is directly related to the outside air temperature.

For the days without missing data, the values of CFM and the outside air temperature (reported by SMUD's Energy Management System) were plotted on a scatter graph. This graph is shown in Figure 46. A linear relation between CFM and outside-air-temperature was found to have an R^2 of 0.7461 and an equation as given below:

$$CFM = (72.802 \times T_{O?A}) + 13769 \qquad \text{- Eqn. 6}$$

CFM = Hourly averaged conditioned air being delivered into the space in cubic feet per minute

$T_{O/A}$ = Outside air temperature

The above equation of this linear relation was then used to predict CFM for the missing days.

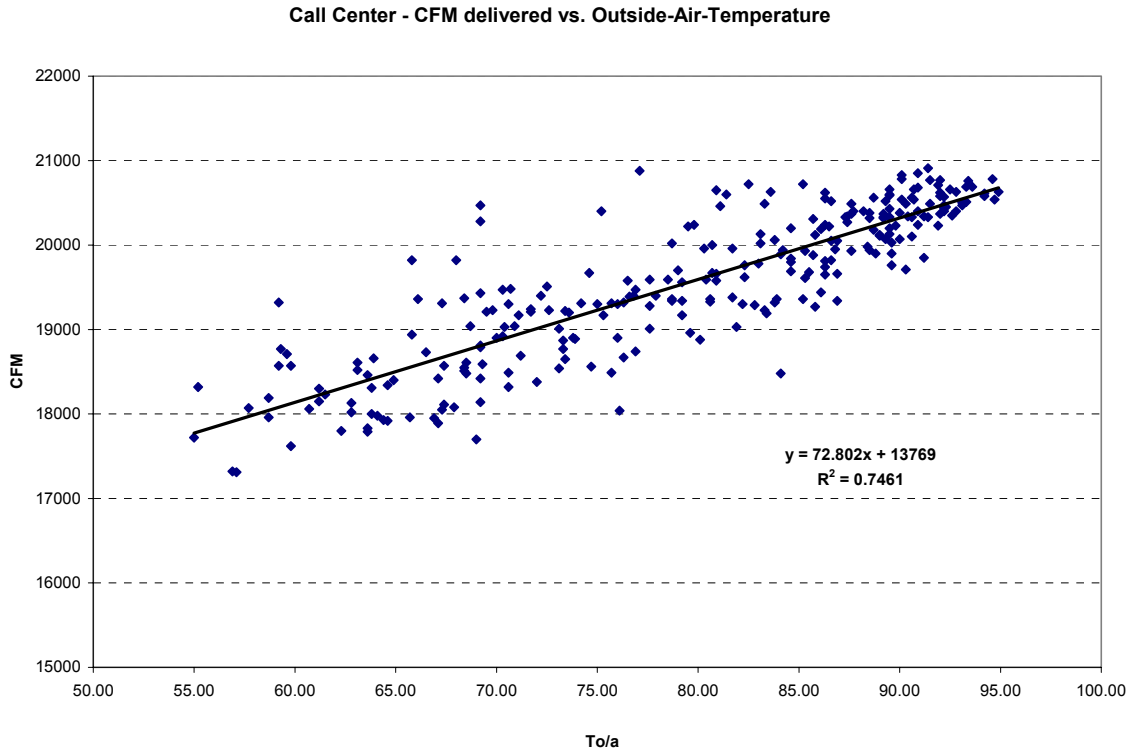


Figure 46: Scatter graph of CFM delivered vs. Outside-Air-Temperature ($T_{O?A}$).

9.3 Ventilation Rates for Desktop Study

An attempt was made to calculate the outside air CFM for the Desktop study, similar to the one done in the Call Center study. However, due to lack of sufficient data from the EMS, for our test days we were unable to provide a accurate outside air CFM for the given test days.

During our study, some data that could not be measured or recorded by our survey team was requested from SMUD's Energy Management System. We requested SMUD for outside air temperature ($T_{O/A}$) recorded at a weather station located on the SMUD building site, return air temperatures from the conditioned spaces in all the spaces considered for this study (T_{return}), and amount of conditioned air being delivered to each of these spaces (CFM). We requested this data for the entire period of our study. Unfortunately, the data set provided to us had critical pockets of missing data. These missing pockets of data coincided with the days we administered the mini-tests—the time period we most needed for the analysis. We administered the mini-tests on October 24th and 31st, November 7th, 14th and 21st. Of these days, we received data for only October 24th and November 14th for the CSC building due to problems with the EMS system data collection routine.

We had the option of performing an exercise similar to the call center study outside air CFM calculations for the side-by-side study. However, it was not possible to account for the variance in weather over the side-by-side study period with such limited data to manipulate.

The CSC building HVAC system is complex with multiple air handlers serving multiple thermal zones on multiple floors. Each floor is composed of up to three core zones and three perimeter zones, all of which are supplied by different air handlers (see section “CSC Building description” in main report) . There was no clear metric as to what quantity of air supplied by each air handler went to each of its related spaces. Thus while we could calculate the total CFM supplied by a given air handler, we did not have any metric for distributing that CFM reliably between the six of eight thermal zones that air handler supplied.

In view of these data limitations and the complex nature of the system, we decided not to pursue the outside air CFM as a variable in our analysis of the side-by-side study.